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Volume 17

TOPEX Radar Altimeter Engineering Assessment Report Update - Side B Turn-On to January 1, 2003

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About the Series

The TOPEX Radar Altimeter Technical Memorandum Series is a collection of performance assessment documents produced by the NASA Goddard Space Flight Wallops Flight Facility over a period starting before the TOPEX launch in 1992 and continuing over greater than 10 year TOPEX lifetime. Because of the mission's success over this long period and because the data are being used internationally to redefine many aspects of ocean knowledge, it is important to make a permanent record of the TOPEX radar altimeter performance assessments which were originally provided to the TOPEX project in a series of internal reports over the life of the mission. The original reports are being printed in this series without change in order to make the information more publicly available as the original investigators become less available to explain the altimeter operation and details of the various data anomalies that have been resolved.

Foreword

The Engineering Assessment of the TOPEX Radar Altimeter is performed on a continuing basis by the TOPEX Altimeter Team at NASA / GSFC Wallops Flight Facility. The Assessment Team members are:

David W. Hancock III / NASA: TOPEX Altimeter Verification Manager / Team Leader
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For the latest updates on the performance of the TOPEX Radar Altimeter, and for accessing many of our reports, readers are encouraged to contact our WFF / TOPEX Home Page at http: / / topex.wff.nasa.gov.

For additional information on this topic, please contact the Team Leader, David W. Hancock III. He may be reached at 757-824-1238 (Voice), 757-824-1036 (FAX), or by e-mail at David.W.Hancock@nasa.gov.

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Section 1

Introduction

1.1 Identification of Document

This is the tenth in a series of TOPEX Radar Altimeter Engineering Assessment Reports.

The initial TOPEX Radar Altimeter Engineering Assessment Report, in February 1994, presented performance results for the NASA Radar Altimeter on the TOPEX/POSEIDON spacecraft, from the time of its launch in August 1992 to February 1994. Since the time of that initial report and prior to this report, there have been eight interim supplemental Engineering Assessment Reports, issued in March 1995, May 1996, March 1997, June 1998, August 1999, September 2000, June 2001, and again in March 2002.

The sixth supplement in September 2000 was the first assessment report that addressed Side-B performance, and presented the altimeter performance from the turn-on of Side-B until the end of calendar year 1999. This report extends the performance assessment of Side B to the end of calendar year 2002 and includes the performance assessment of Jason-1, the TOPEX follow-on mission, launched on December 7, 2001.

Over the years since TOPEX/POSEIDON launch, we have performed a large variety of TOPEX performance studies; Appendix A provides an accumulative index of those studies. As the performance database has expanded, and as analysis tools and techniques continue to evolve, the longer-term trends of the altimeter data have become more apparent. The updated findings are presented here.

Section 2

On-Orbit Instrument Performance (Cycles 343 through 378)

From the time of the initial turn-on of Side B on February 10, 1999, to the end of 2002, the NASA Radar Altimeter has been in TRACK mode for a total of approximately 32,000 hours. The altimeter has been in IDLE mode for an additional 1880 hours, generally due to the French Altimeter's being turned on. The French Altimeter has been turned on only once since January 23, 2001; that was during cycle 361 (2002 / 183-21002 / 193).

The NASA altimeter has been OFF for a total of 51 hours, attributable to: a 16-hour spacecraft level safehold on August 31, 1999; a related 8-hour OFF status three days later to switch the spacecraft attitude control electronics on September 3, 1999; and a 27-hour spacecraft level safehold on November 24, 2000. Since the start of 2001, the altimeter has never been in OFF mode.

Since the Jason-1 launch on December 7, 2001, TOPEX flew in tandem for approximately 240 days with measurements separated by 73 seconds, until transferred to the new interspaced orbit. TOPEX / Poseidon was transferred to a new obit during cycle 368 (2002 / 227 to 2002 / 259), 1282 days from Side B turn-on. To the end of the assessment period (January 1, 2003) covered by this report, TOPEX has been in the new interspaced orbit for a total of 105 days.

The succeeding sub-sections discuss:

- Side B internal calibration results
- Side B cycle summary results
- Side B key events
- Side B abnormalities

2.1 Side B Internal Calibrations

The TOPEX altimeter's internal calibration mode has two submodes designated CAL-1 and CAL-2. In CAL-1 a portion of the transmitter output is fed back to the receiver through a digitally controlled calibration attenuator and delay line. The altimeter acquires and tracks this calibration signal for 10 seconds at each of 17 different preset calibration attenuator values; each calibration attenuator value is changed by 2 dB from its neighbor. The altimeter's CAL-1 has almost the same signal path as the normal fine-track mode, except that CAL-1 has a delay line, a different attenuator, and switches to select these components. The altimeter's automatic gain control (AGC) loop is active during each CAL-1 step, so changes in CAL-1 range and AGC should be directly relatable to changes in the altimeter's fine-track range and power estimation. The AGC level of CAL-1 Step 5 best represents the average level seen in normal over-ocean fine-tracking, so CAL-1 Step 5 data are used in the discussions of changes in calibration mode range and power estimates in this report.

When commanded to its calibration mode, the TOPEX altimeter first enters CAL-1 and then CAL-2. Each of the 17 steps within CAL-1 lasts about 10 seconds, and then CAL-2 lasts about a minute, so the entire calibration sequence lasts about 4 minutes. Internal altimeter calibrations are scheduled twice-per-day, over land areas, at approximately 0000 UTC and 1200 UTC. Internal calibrations are also performed whenever the NASA altimeter is commanded from TRACK to IDLE for a period of tracking by the French altimeter, or from IDLE back to TRACK when tracking resumes for the NASA altimeter. The calibrations prior to and after the French altimeter operations are not constrained to land areas, and usually occur over open ocean.

Our processing of the CAL-1 range data was modified in 1994, to remove the effect of the 7.3 mm quantization; the revised method is discussed in Section 2.1.1 (page 2) of the year 1994 supplement (published in March 1995). All the calibration data since launch have been processed using the revised method.

2.1.1 Range Calibrations

The change in Ku-Band range, from Side B turn-on on day 042 of 1999 to the end of 2002, is plotted in Figure 2-1 "Ku-Band Range CAL-1 Results" on page 2-4. CAL-1 steps 4 through 7 are shown in the figure. The Ku-Band delta range shown in Figure 2-1 (and in the succeeding calibration plots) is calculated based on the measurement minus a reference. This calibration range plot indicates that the Side B Ku-Band delta range varied only about ±1 mm from the time of its turn-on to the end of 2001. During 2002, however, the Ku-Band delta range has undergone irregular periods of oscillations that have dipped to the -4 mm level. These oscillations, cause unknown, are discussed in Section 3. In Figure 2-1, the >20 mm decrease at day 1247 (2002193) was caused by bad calibration data during an anomalous altimeter switch over from SSALT to ALT. SSALT experienced an seu, which did not allow transmit power enable. This occurrence is listed in Table 2-2 Side B Key Events, entry Day 2002193.

The change in C-Band calibration range is depicted in Figure 2-2 "C-Band Range CAL-1 Results" on page 2-5. This plot indicates that, during the initial 200 days after turn-on, the Side B C-Band range negatively drifted (i.e., became shorter) by about 8 mm. Since that time, to the end of 2002, there has been a negative drift of approximately 2 mm.

Range calibrations and their correction values are discussed in more detail in Section 3.1.

2.1.2 AGC Calibrations

2.1.2.1 CAL-1 and CAL-2

The change in Side B Ku-Band AGC since launch is shown in Figure 2-3 "Ku-Band AGC CAL-1 and CAL-2 Results" on page 2-6. CAL-1 steps 4 through 6, plus CAL-2, are depicted in the figure. At approximately 210 days after turn-on, there was an apparent step-function change as the Ku AGC increased approximately 0.2 dB. Since the time of that occurrence, the Ku AGC gradually increased another 0.1 dB.

The change in C-Band AGC since Side B turn-on is shown in Figure 2-4 "C-Band AGC CAL-1 and CAL-2 Results" on page 2-7. The Side B AGC has remained at essentially the same level (+0.1 dB) since turn-on.

A more in-depth analysis of the AGC calibrations is presented in Section 3.2.

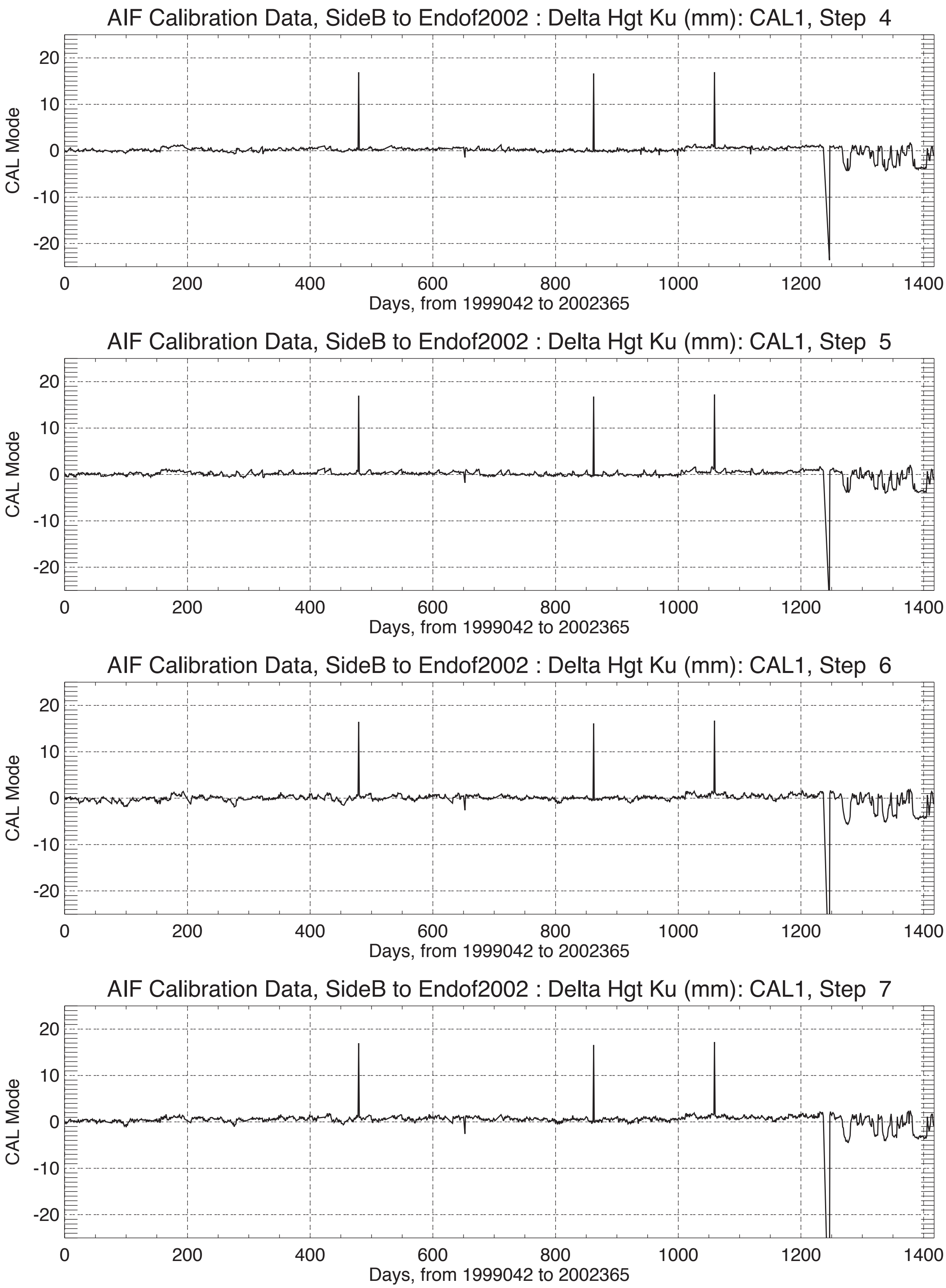


Figure 2-1 Ku-Band Range CAL-1 Results

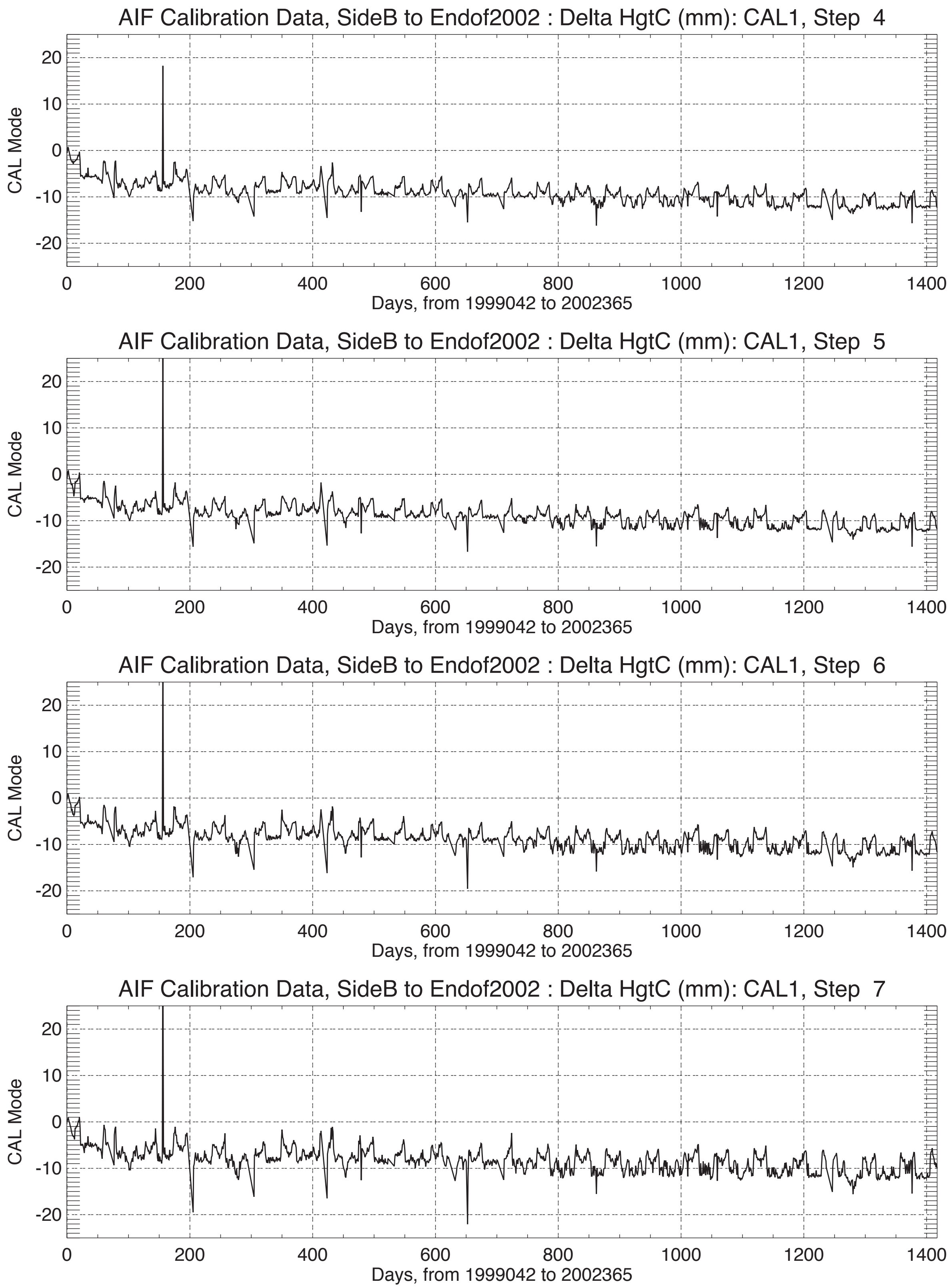


Figure 2-2 C-Band Range CAL-1 Results

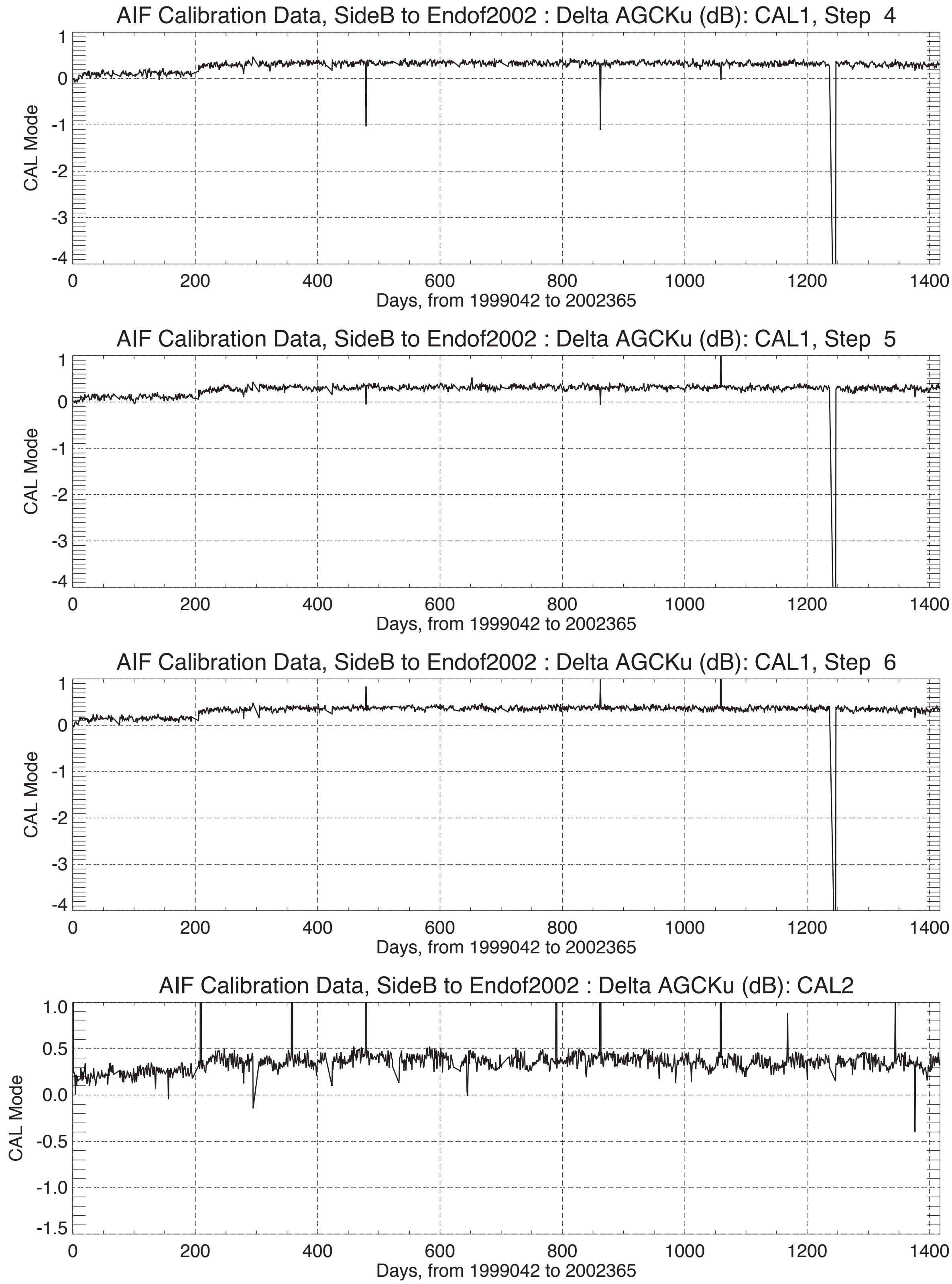


Figure 2-3 Ku-Band AGC CAL-1 and CAL-2 Results

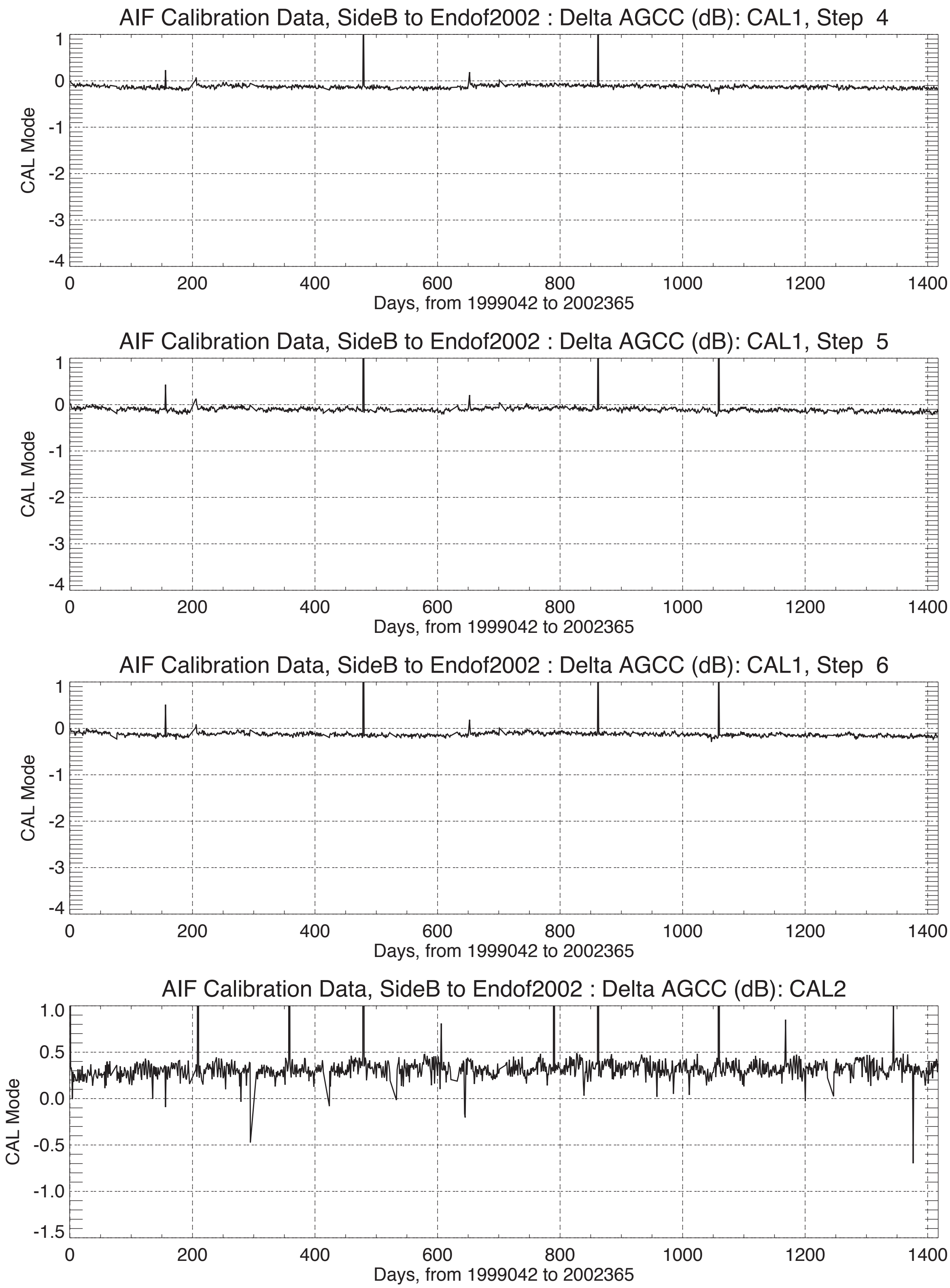


Figure 2-4 C-Band AGC CAL-1 and CAL-2 Results

2.2 Side B Cycle Summaries

The data in the Side B cycle summary plots which follow are extracted from the Geophysical Data Record (GDR) database at WFF. The criteria for TOPEX GDR measurements to be accepted for the WFF database are: 1) the data are classified as Deep Water; 2) the data are in normal Track Mode; and 3) selected data quality flags are not set.

For each measurement type, the plots contain one averaged measurement per cycle. The cycle average value is itself the mean of one-minute along-track boxcar averages, after editing. Data are excluded from the averaging process whenever the one-minute-averaged off-nadir angle exceeds 0.12 degree or the averaged Ku-Band sigma0 exceeds 16 dB or whenever the number of non-flagged frames within the one-minute interval is fewer than 45. These edit criteria primarily have to do with eliminating the effects of sigma0 blooms. As a result of this edit, approximately 15% of the database measurements are excluded from the averaging process. This tight editing is part of our effort to ensure that anomalous data are excluded from the performance assessment process.

2.2.1 Sea Surface Height

The sea surface heights (ssh) contained in the GDR files are based on combined heights. Cycle-average ssh are shown in Figure 2-5 "Cycle-Average Sea Surface Height in Meters". It is not possible to discern range drifts at the millimeter level from these data, but seasonal variations of global sea level are observable. [There are 36.8 cycles per year.]

There is an anomalous ssh peak between cycles 365 and 368 (2002/227-to-2002/259). This peak is correlated with the period of orbit maneuvers that transferred TOPEX/Poseidon to a different orbit.

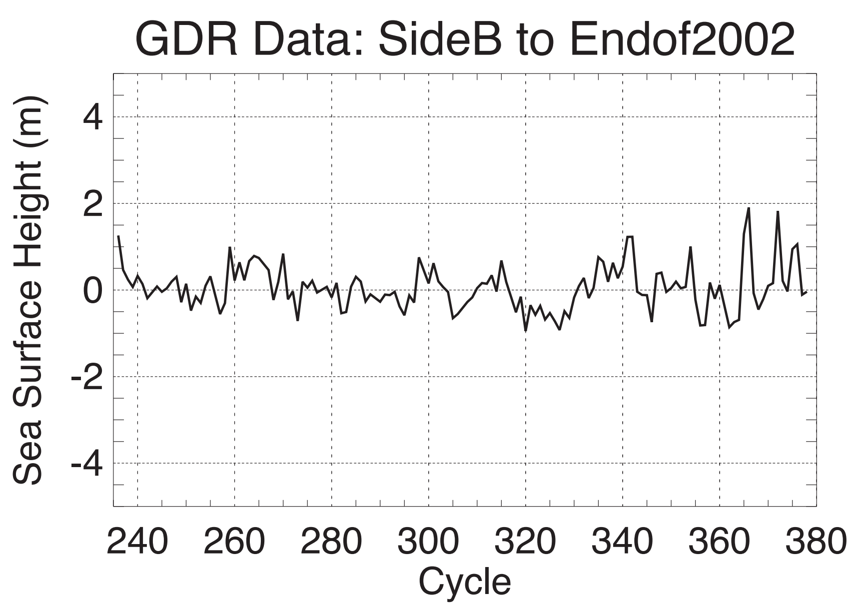


Figure 2-5 Cycle-Average Sea Surface Height in Meters

2.2.2 Sigma0

The sigma0 cycle-averages are plotted in Figure 2-6 and Figure 2-7 for Ku-Band and C-Band, respectively. The GDR calibrated Ku-Band sigma0 has generally remained in a band between 10.95 and 11.30 dB, while the C-Band has been in a band between 14.40 and 14.80 dB.

Sigma0 trends are discussed in more detail in Section 3.2.

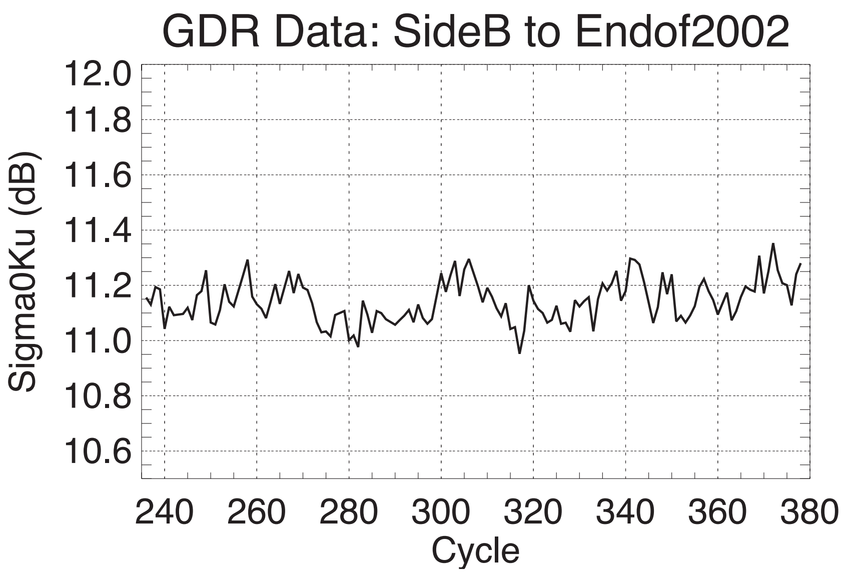


Figure 2-6 Cycle-Average Ku-Band Sigma0 in dB

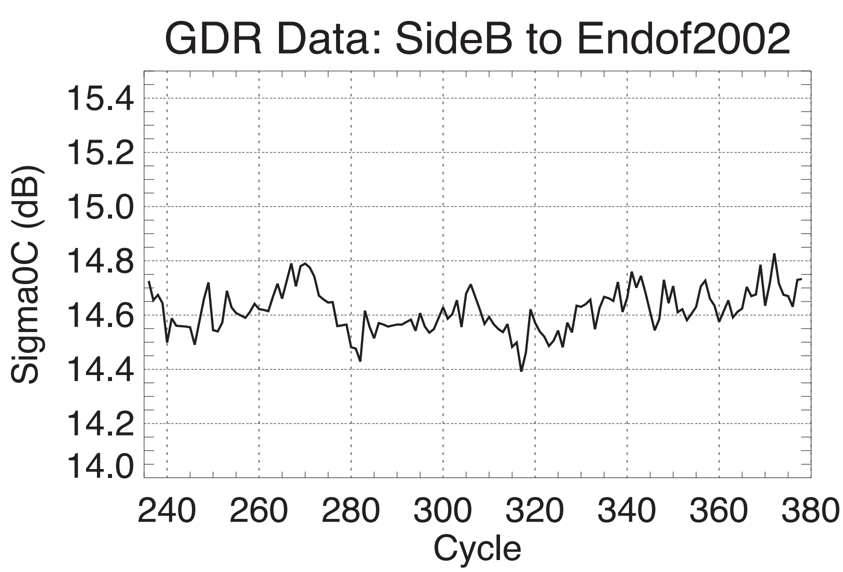


Figure 2-7 Cycle-Average C-Band Sigma0 in dB

2.2.3 Significant Wave Height

Ku-Band cycle-averages for significant wave height (SWH) are shown in Figure 2-8 and C-Band cycle-averages for significant wave height (SWH) are shown in Figure 2-9. Seasonal trends in SWH are observable. Section 4.2 provides a monitor of Ku-Band / C-Band parameter differences.

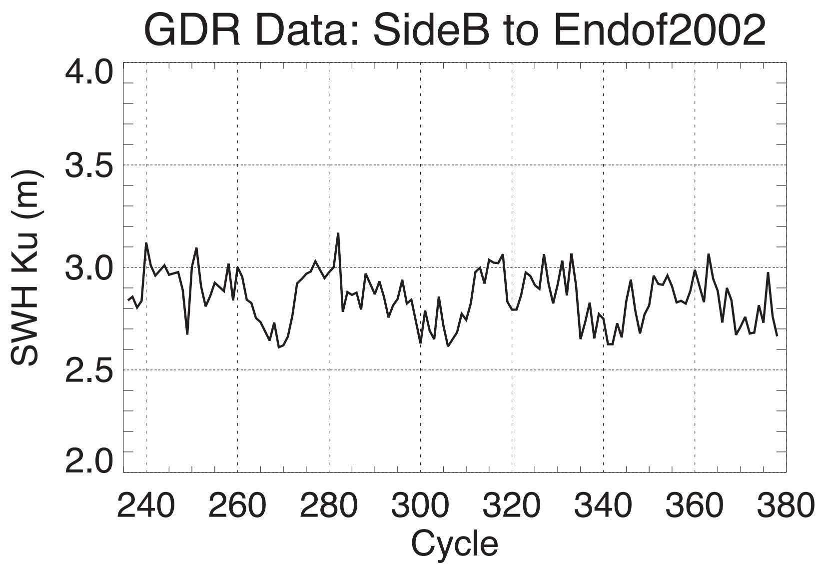


Figure 2-8 Cycle-Average Ku-Band Significant Wave Height in Meters

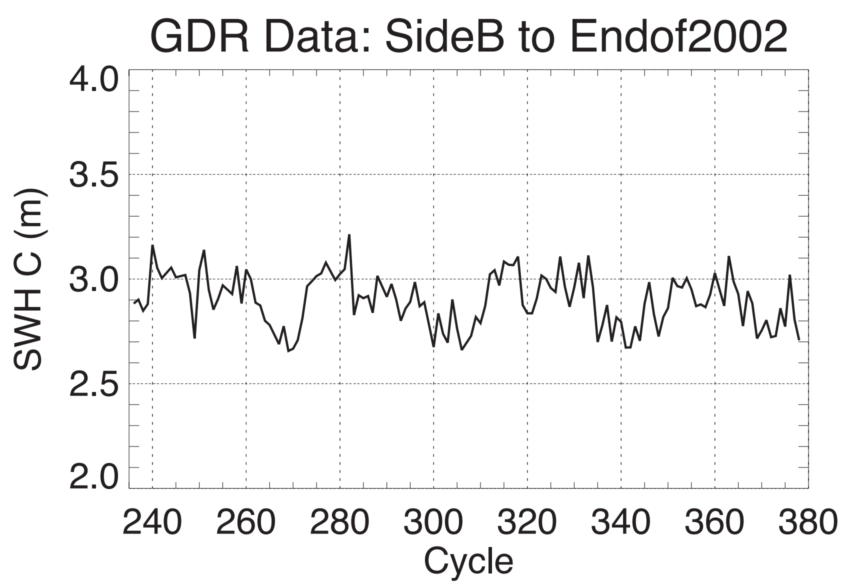


Figure 2-9 Cycle-Average C-Band Significant Wave Height in Meters

2.2.4 Range RMS

The calculated Ku-Band range rms values depicted in Figure 2-10 are based on the rms derivation described in Section 5.1.1 of the February 1994 Engineering Assessment Report. An expected correlation with SWH is apparent.

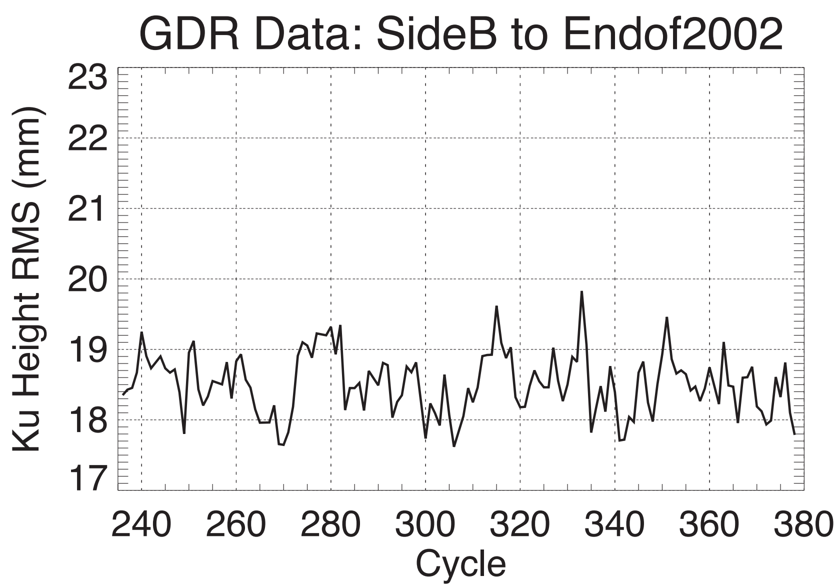


Figure 2-10 Cycle-Average Ku-Band Range RMS in Millimeters

2.2.5 Waveform Monitoring

Selected telemetered waveform gates during CAL-2 and STANDBY modes are monitored daily, to discern waveform changes throughout the mission. CAL-2 waveform sets are generally available twice per day, during calibrations. STANDBY waveforms are generally available four times per day, since the altimeter passes through STANDBY mode just prior to and immediately after each CALIBRATE mode. The relationship of telemetered waveform sample numbers to the onboard waveform-sample numbers is listed in Table 6.2.1 of the February 1994 Engineering Assessment Report.

For both Ku-Band and C-Band, the monitored waveform samples are as follows: CAL-2 gates 23, 29, 48, and 93; and STANDBY gates 38, 39, 68, and 69. The Ku-Band waveform sample history is shown in Figure 2-11 "Ku-Band CAL-2 Waveform Sample History" on page 2-12 and in Figure 2-12 "Ku-Band STANDBY Waveform Sample History" on page 2-13 for CAL-2 and STANDBY, respectively. The C-Band waveform history is depicted in Figure 2-13 "C-Band CAL-2 Waveform Sample History" on page 2-14 and in Figure 2-14 "C-Band STANDBY Waveform Sample History" on page 2-15, respectively, for CAL-2 and STANDBY.

The monitored Ku-Band CAL-2 waveform samples for Sides B in Figure 2-11 have each varied less than 1% throughout the mission, and exhibit little or no temperature dependence.

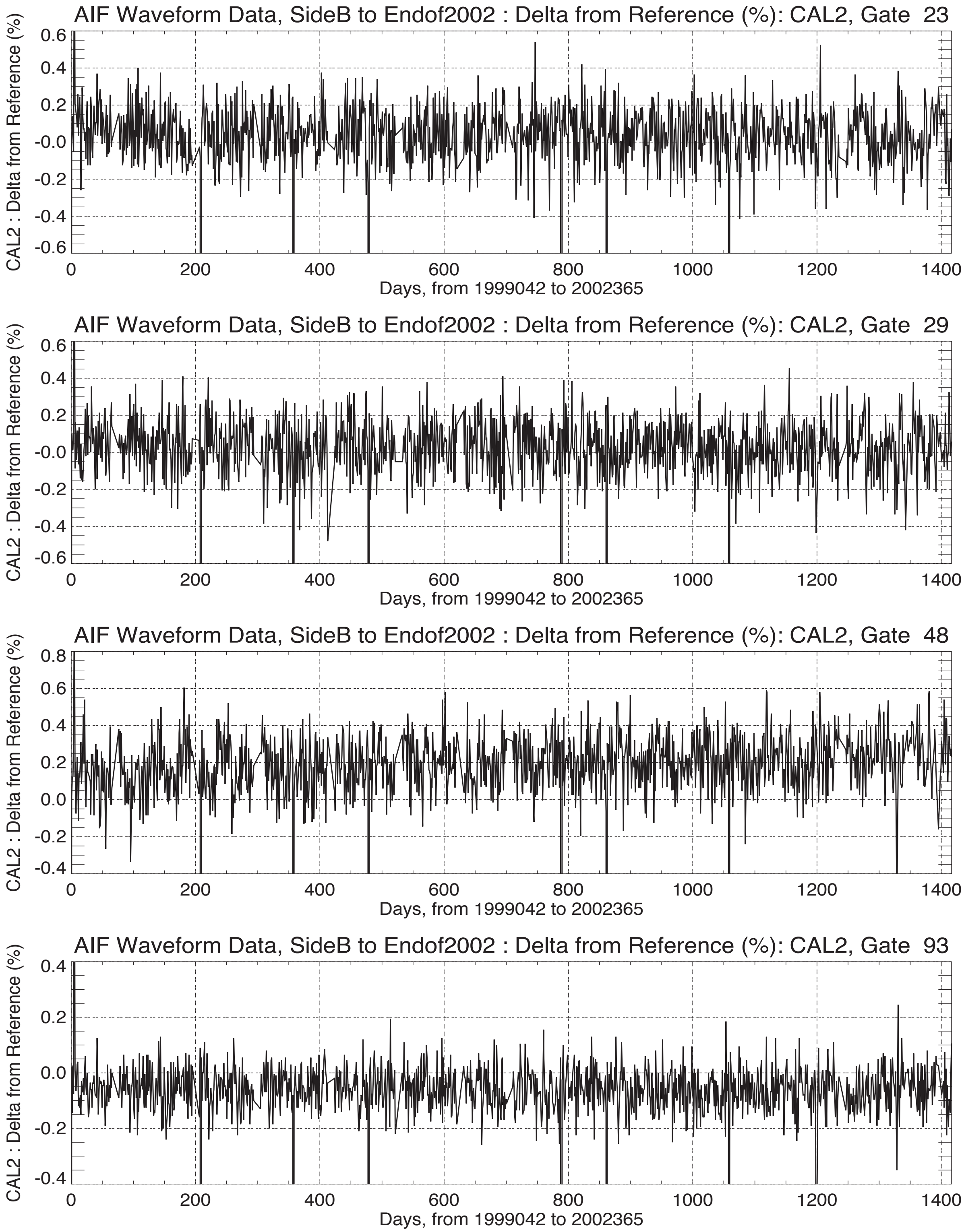


Figure 2-11 Ku-Band CAL-2 Waveform Sample History

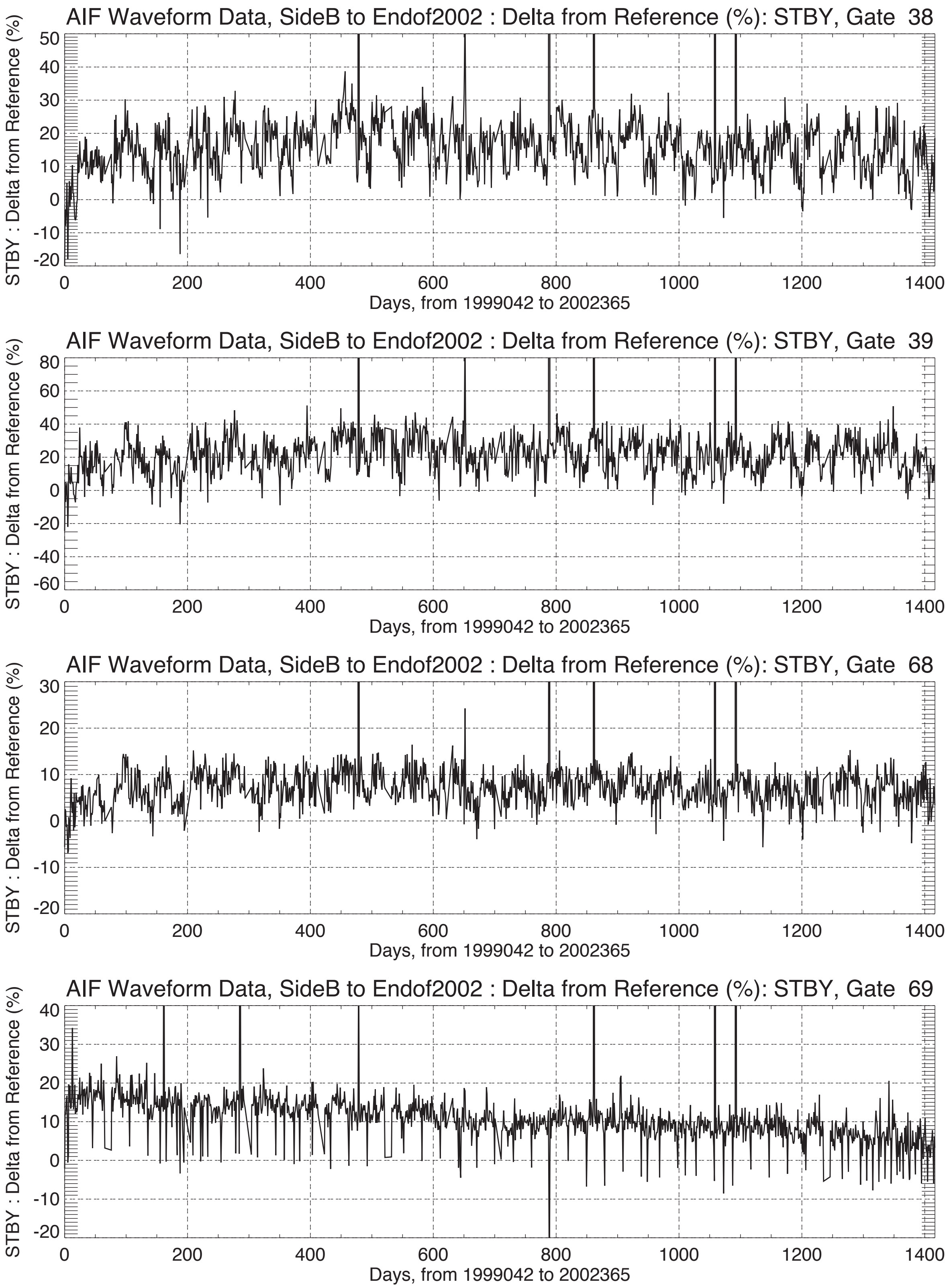


Figure 2-12 Ku-Band STANDBY Waveform Sample History

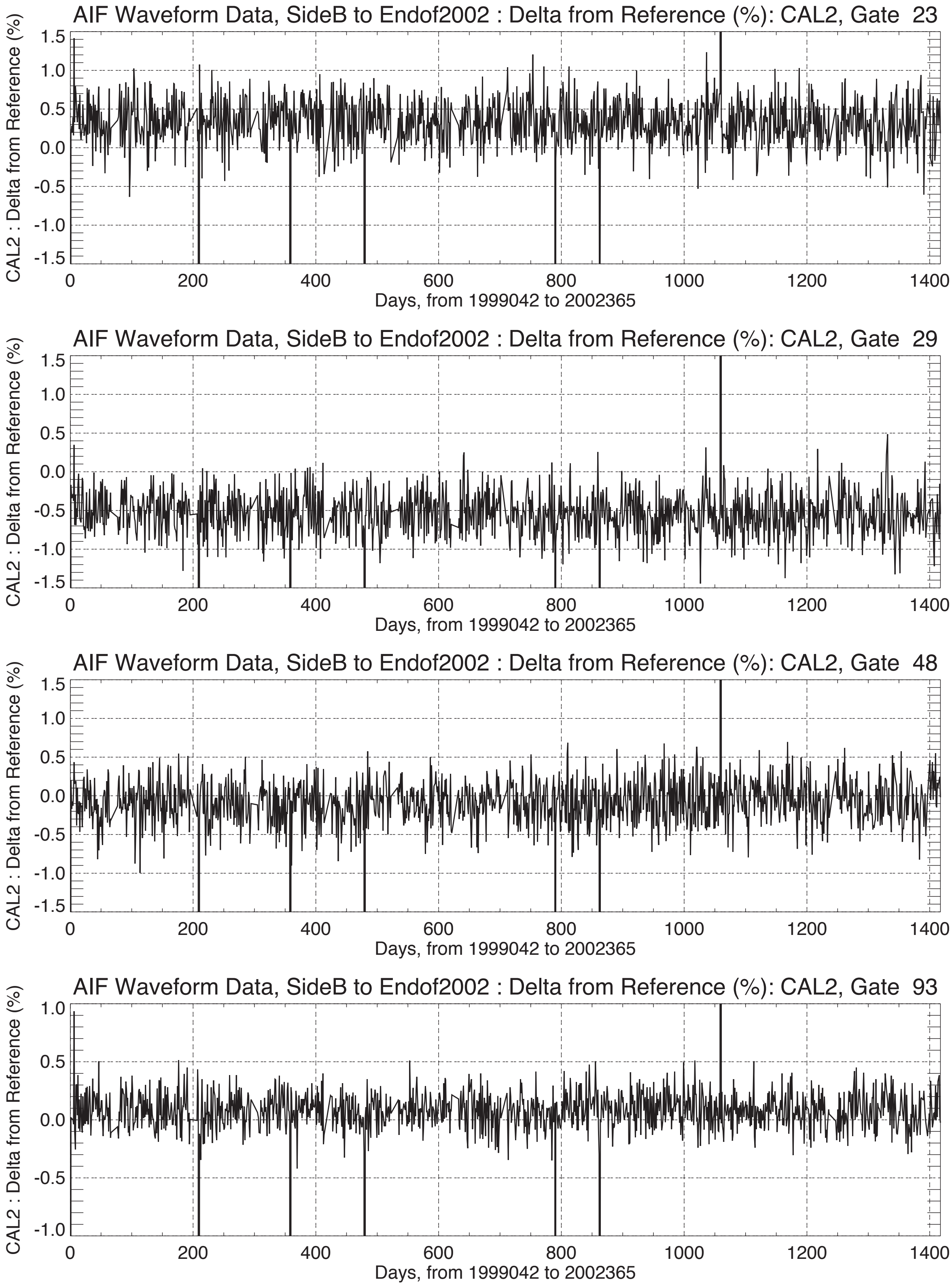


Figure 2-13 C-Band CAL-2 Waveform Sample History

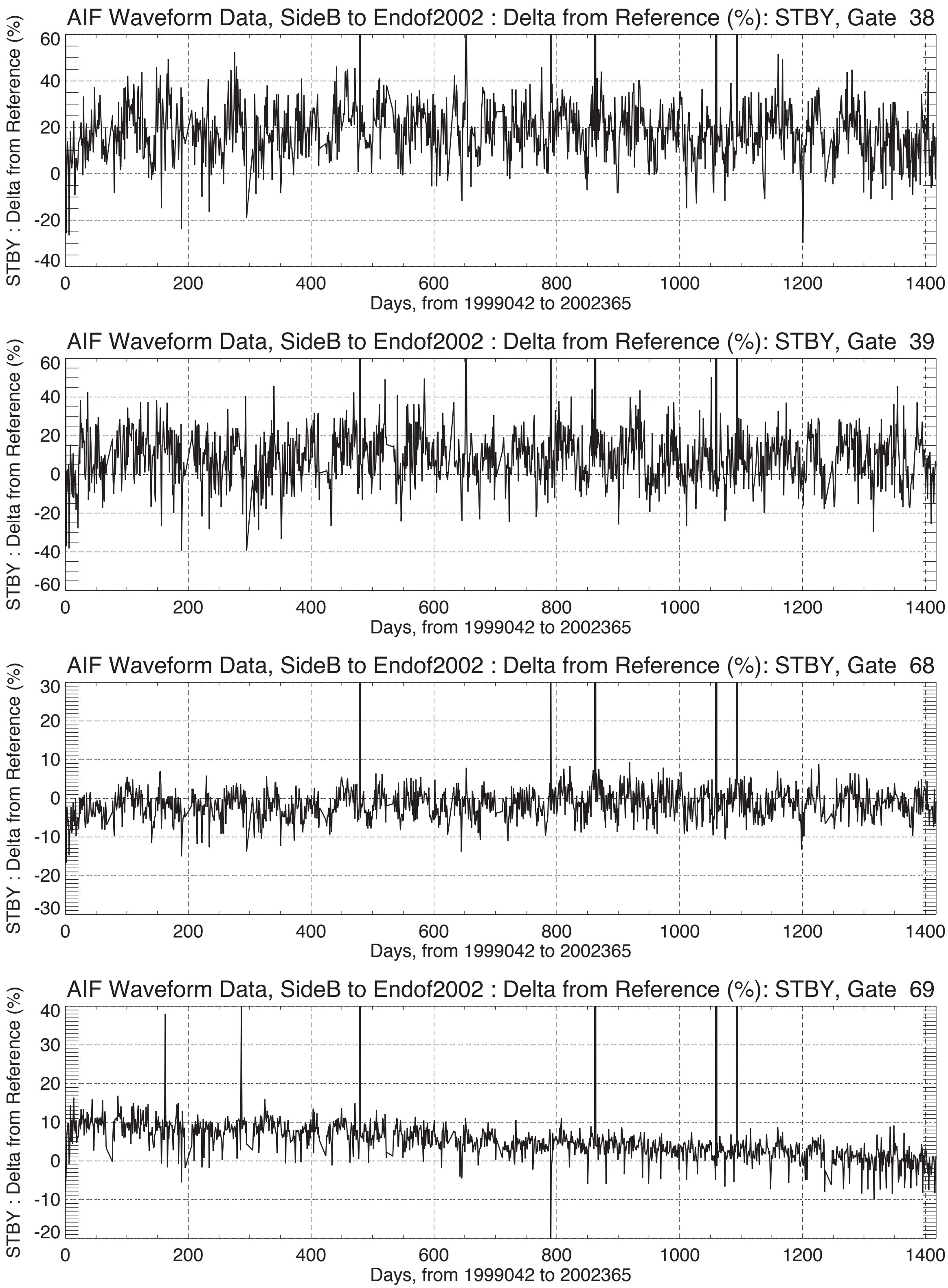


Figure 2-14 C-Band STANDBY Waveform Sample History

The Ku-Band STANDBY waveform samples in Figure 2-12, in contrast, have a slight inverse dependence on temperature (launch-to-date temperatures are shown in Figure 2-15 on the same horizontal time scale as the waveform samples). From the time of Side B turn-on, each of the four sampled gates quickly increased between 5% and 20%, and has then remained fairly steady. Gate 69 is continuing to decrease slightly.

The Side B C-Band CAL-2 waveforms samples, shown in Figure 2-13, are similar to the Ku-Band CAL-2 waveforms in that they have varied less than about 1%, and exhibit no apparent temperature dependence. They differ from Ku-Band, however, in that there are small C-Band changes in amplitude, commencing near the beginning of the year 2001 (around day 685 in the figure); Gates 23 and 93 have both decreased in amplitude by about 0.3%. Gates 29 and 48 have increased in amplitude approximately 0.5% and 0.3%, respectively. All four gates show decreased variability after day 685. The cause of these waveform changes is not understood at this time.

The C-Band STANDBY waveform samples, shown in Figure 2-14, are similar to their counterpart Ku-Band STANDBY waveforms in that Gates 38, 39, 68, and 69 have an inverse dependence on temperature, and have each experienced increases shortly after turn-on. Similar to the C-Band CAL-2 waveforms, however, there are changes in the C-Band STANDBY waveforms beginning around day 685. Gate 38 exhibits reduced variability after day 685, while the amplitudes for gates 39, 68, and 69 show increases of approximately 10%, 10%, and 5%, respectively. The cause of these waveform changes is not understood at this time.

In Figure 2-13, "C-Band CAL-2 Waveform Samples", there are waveform spikes at the labeled days of 210, 359, 480, 800 and 861. The reasons for these spikes are posted in the "Side B Key Events", section 2.3, Table 2-2. They are: Day 210 - 1999/252, Digital Filter Bank Calibration; Day 359 - 2000/036, Digital Filter Bank Calibration; Day 480 - 2000/157, Improper SEU recovery from a Digital Filter Bank Interface Lockup; Day 800-2001/112, Improper SEU recovery; Day 861-2001/173 Improper SEU recovery.

2.2.6 Engineering Monitors

Altimeter temperatures, voltages, powers and currents continue to be monitored. The system remains very stable, with no significant changes since Side B turn-on. The engineering monitor plots presented in this section contain data based on 24-hour time periods, showing the average, the minimum, and the maximum values during each 24-hour period.

2.2.6.1 Temperatures

The temperatures of all 26 internal thermistors continued to be within the design temperature range and, except for the DCG Gate Array, are within the ranges experienced during the pre-launch Hot and Cold Balance Tests. The minimum/maximum values for each of the thermistors during TRACK mode remained within the bounds listed in Table 7.1 of the TOPEX Mission Engineering Assessment Report, February 1994, and they compose plots 2 through 27 in Figure 2-15 "Engineering Monitor Histories" on page 2-17.

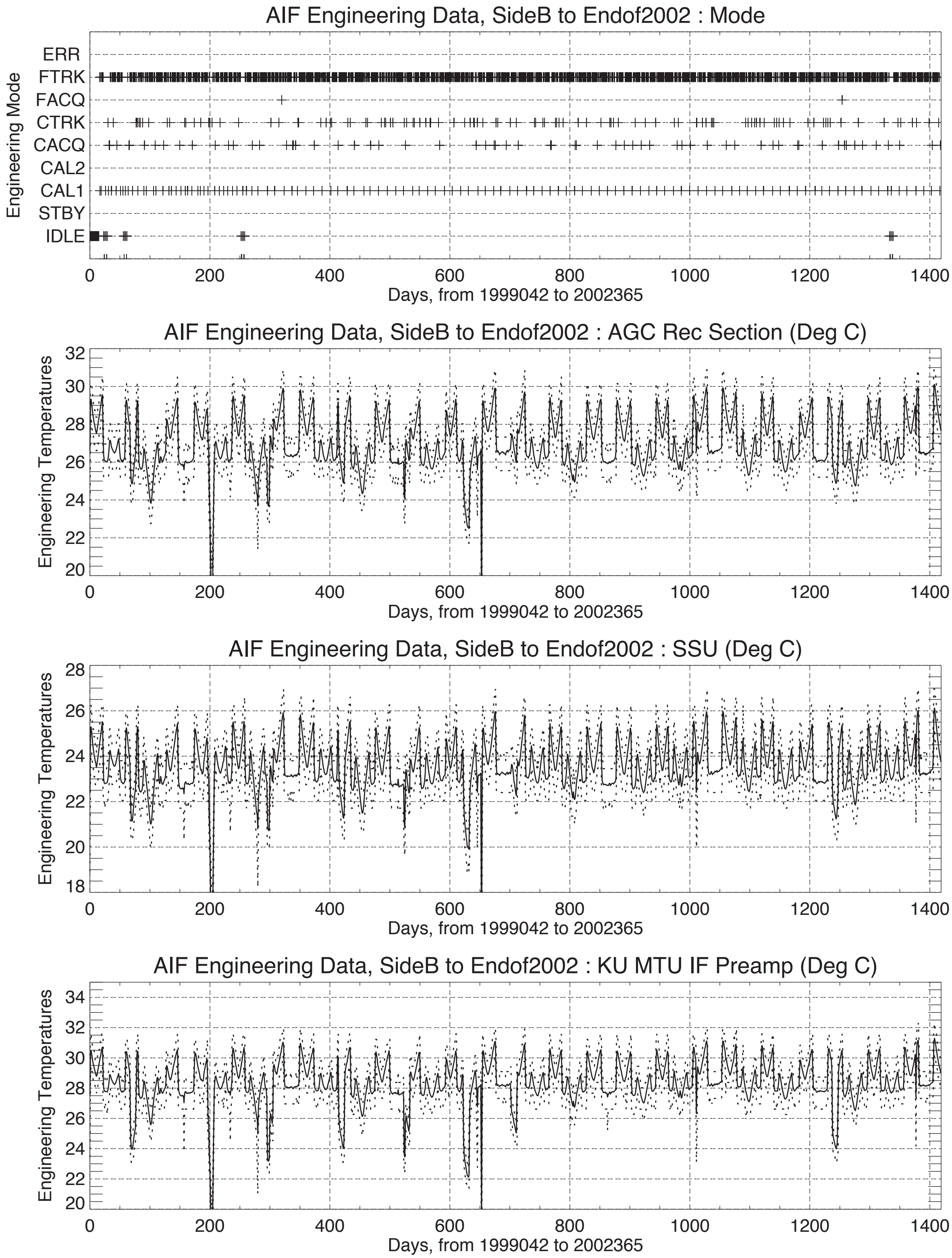


Figure 2-15 Engineering Monitor Histories

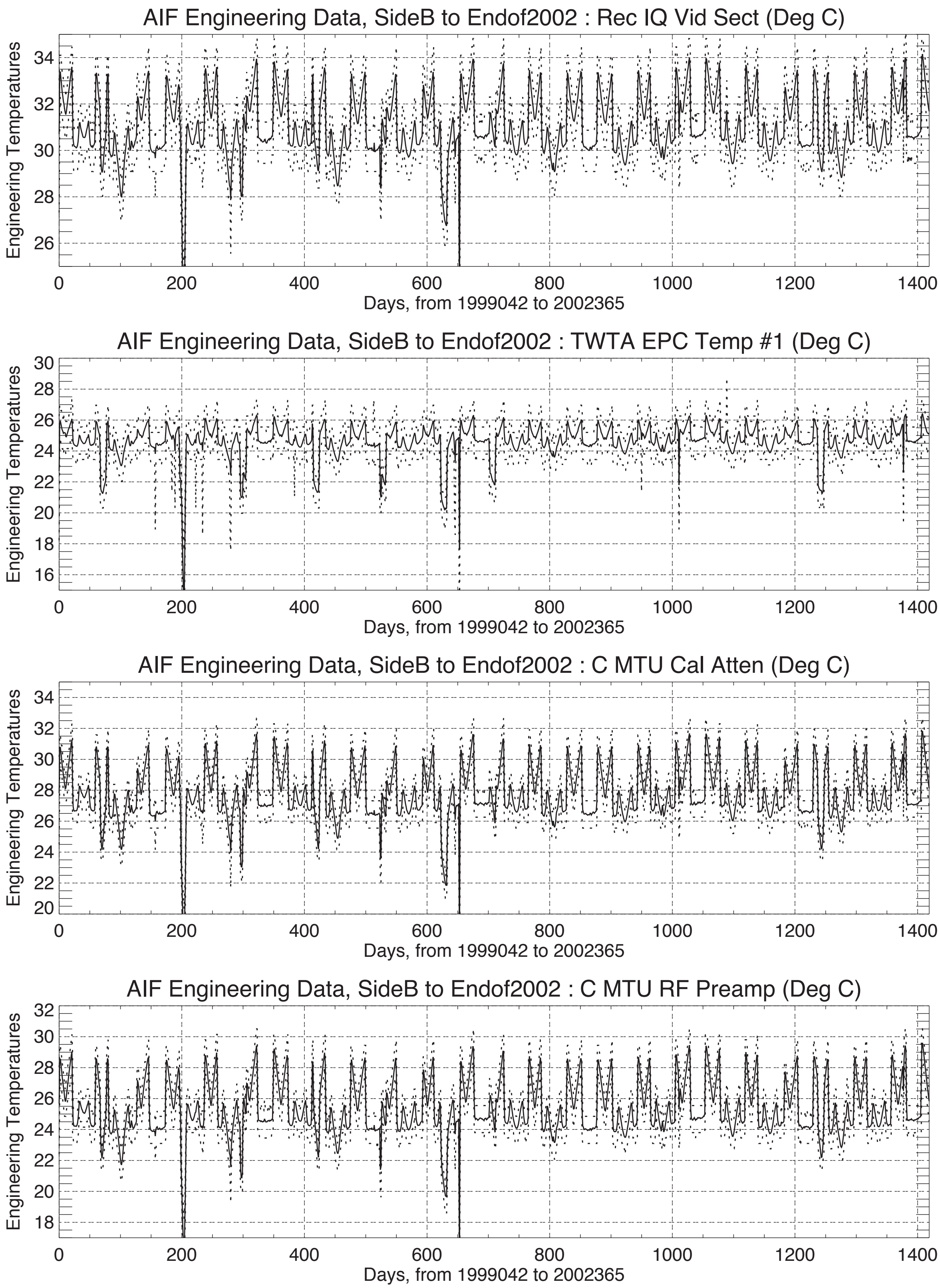
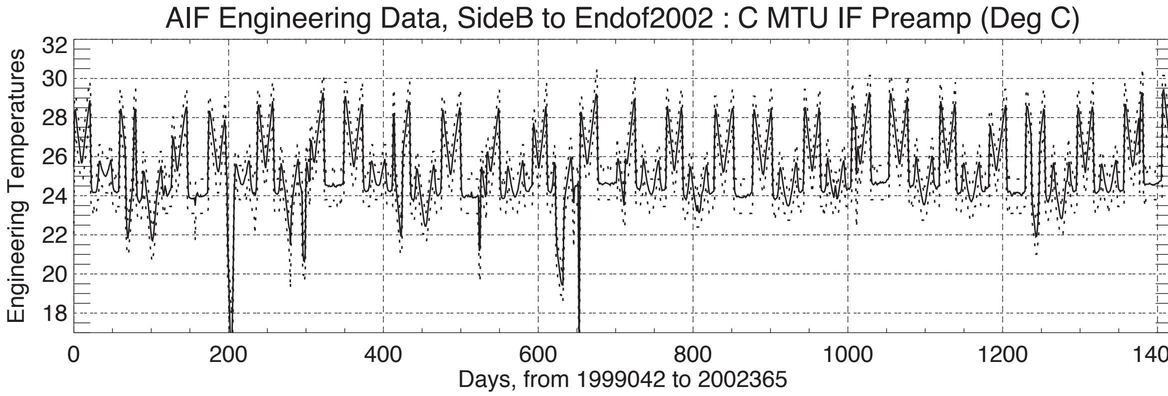
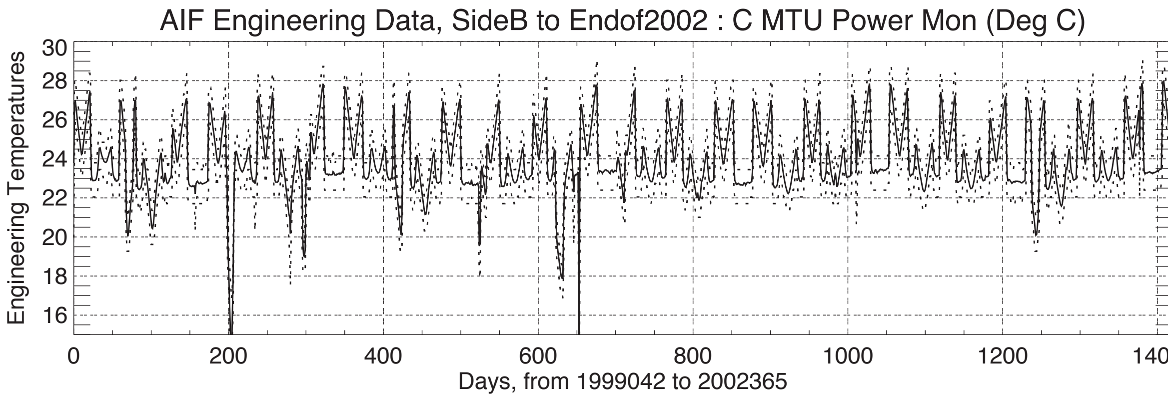
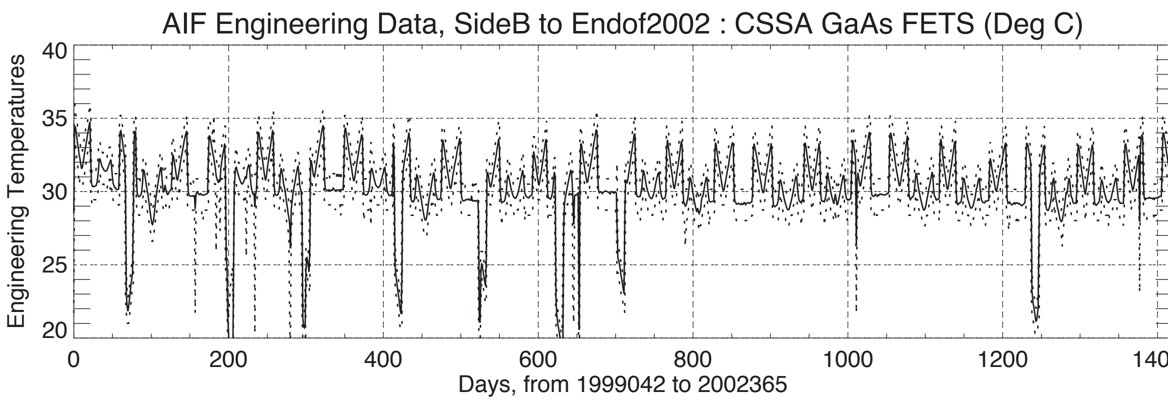


Figure 2-15 Engineering Monitor Histories (Continued)







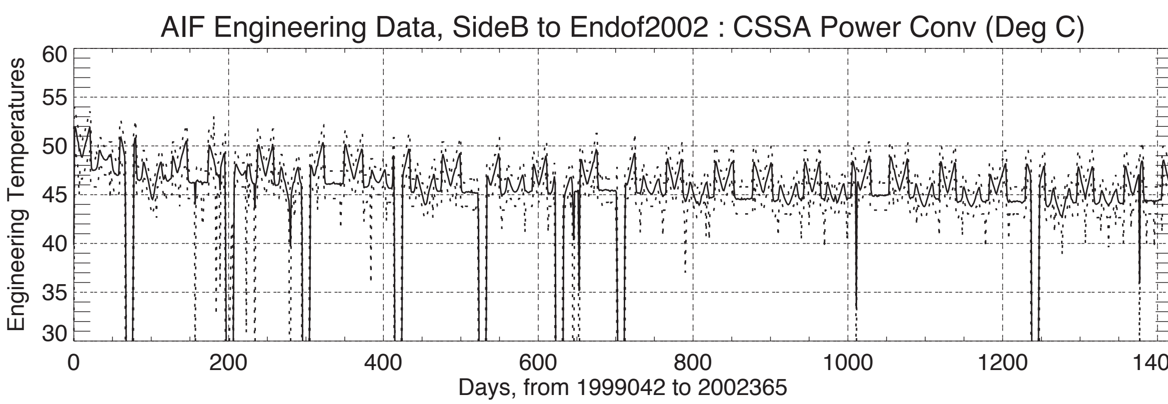
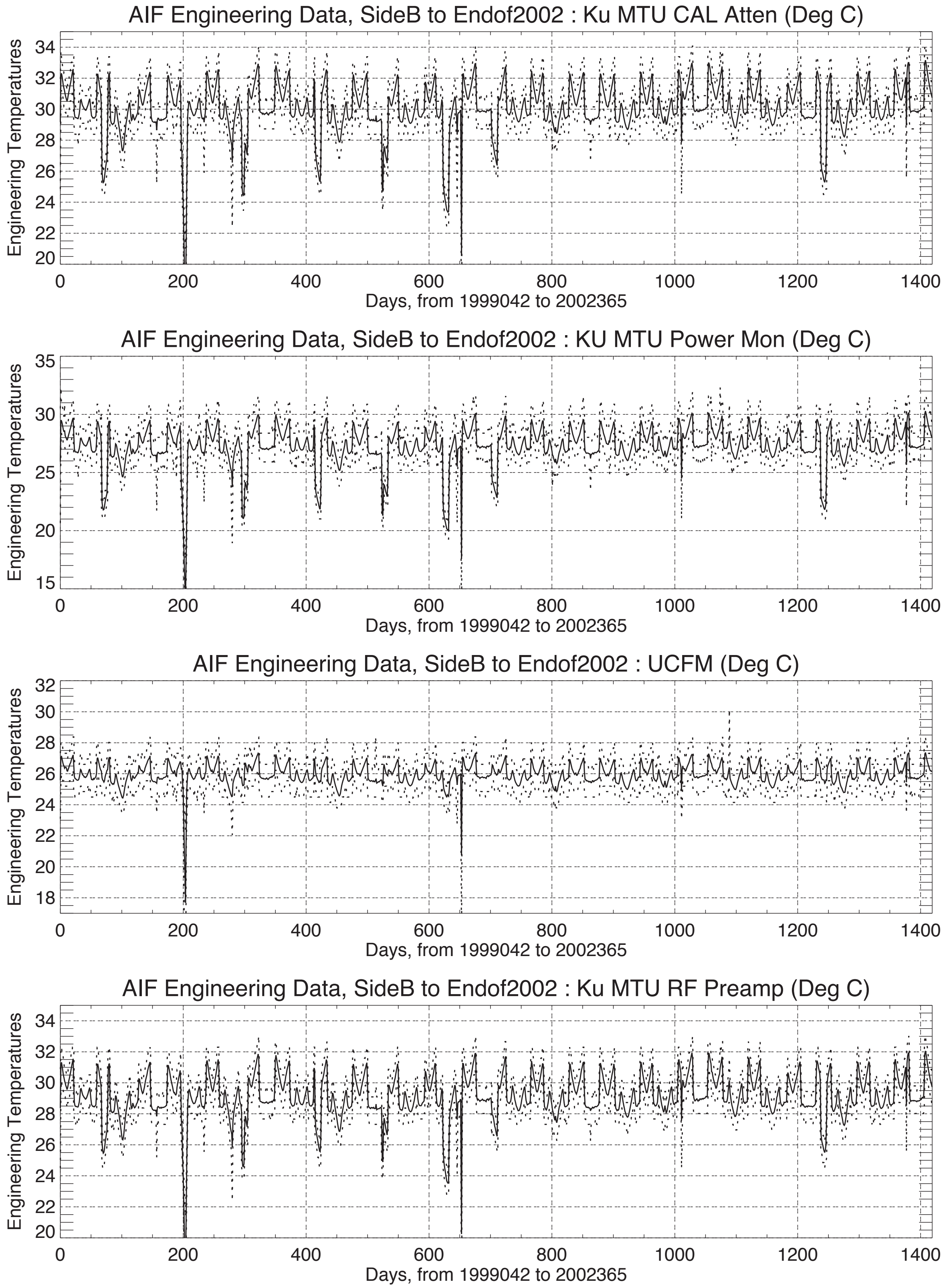


Figure 2-15 Engineering Monitor Histories (Continued)



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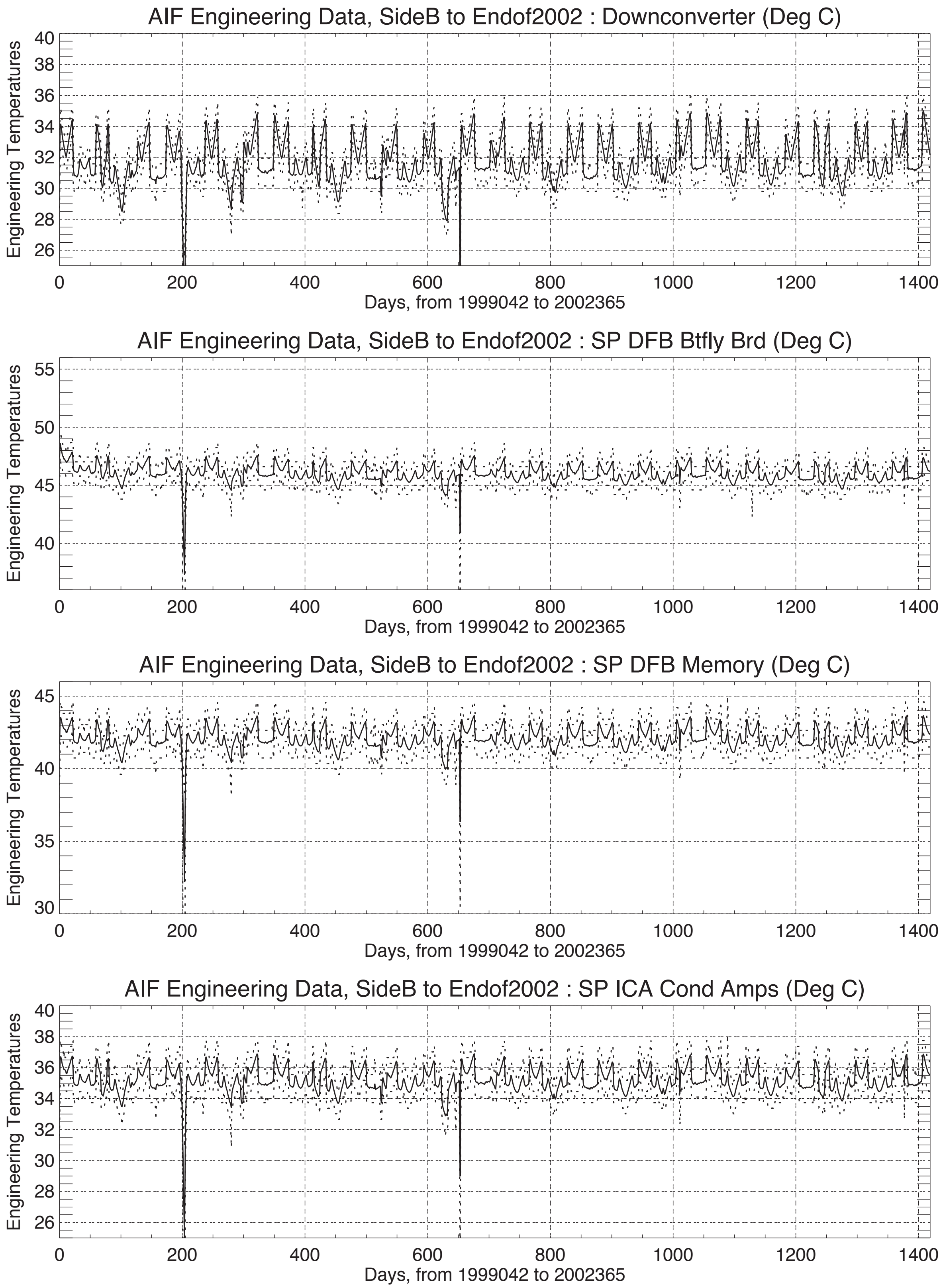

Figure 2-15 Engineering Monitor Histories (Continued)

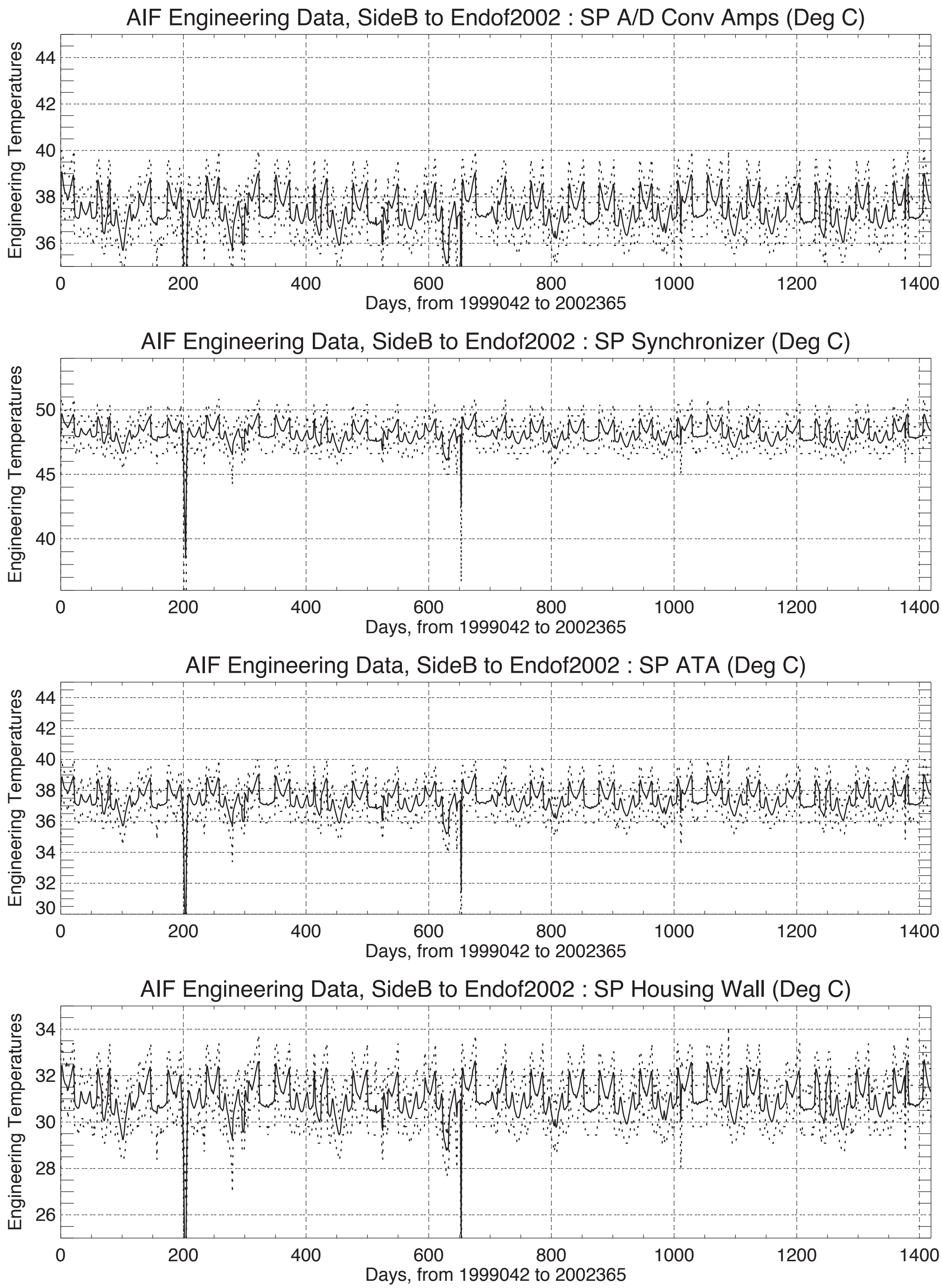

Figure 2-15 Engineering Monitor Histories (Continued)

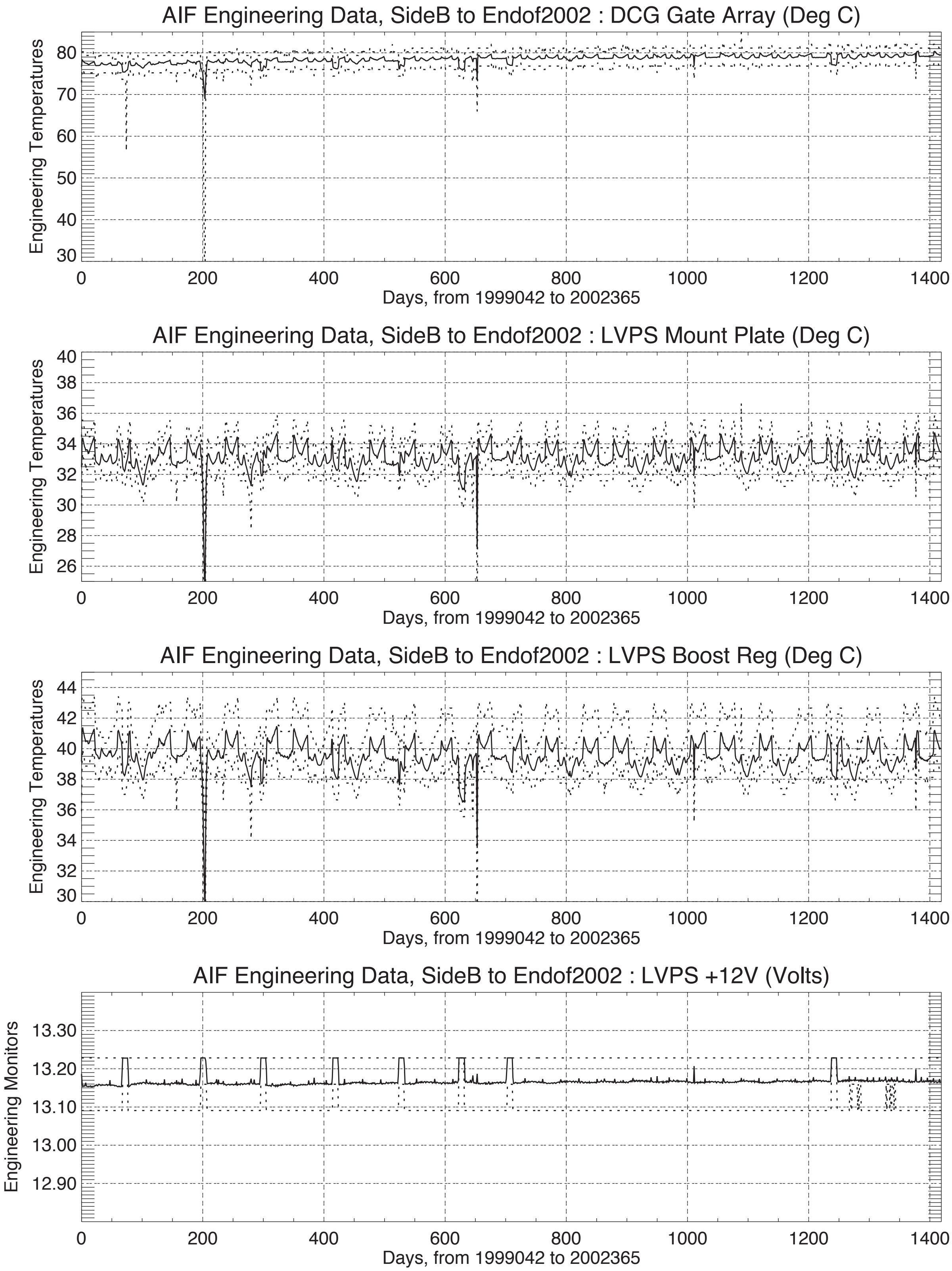

Figure 2-15 Engineering Monitor Histories (Continued)

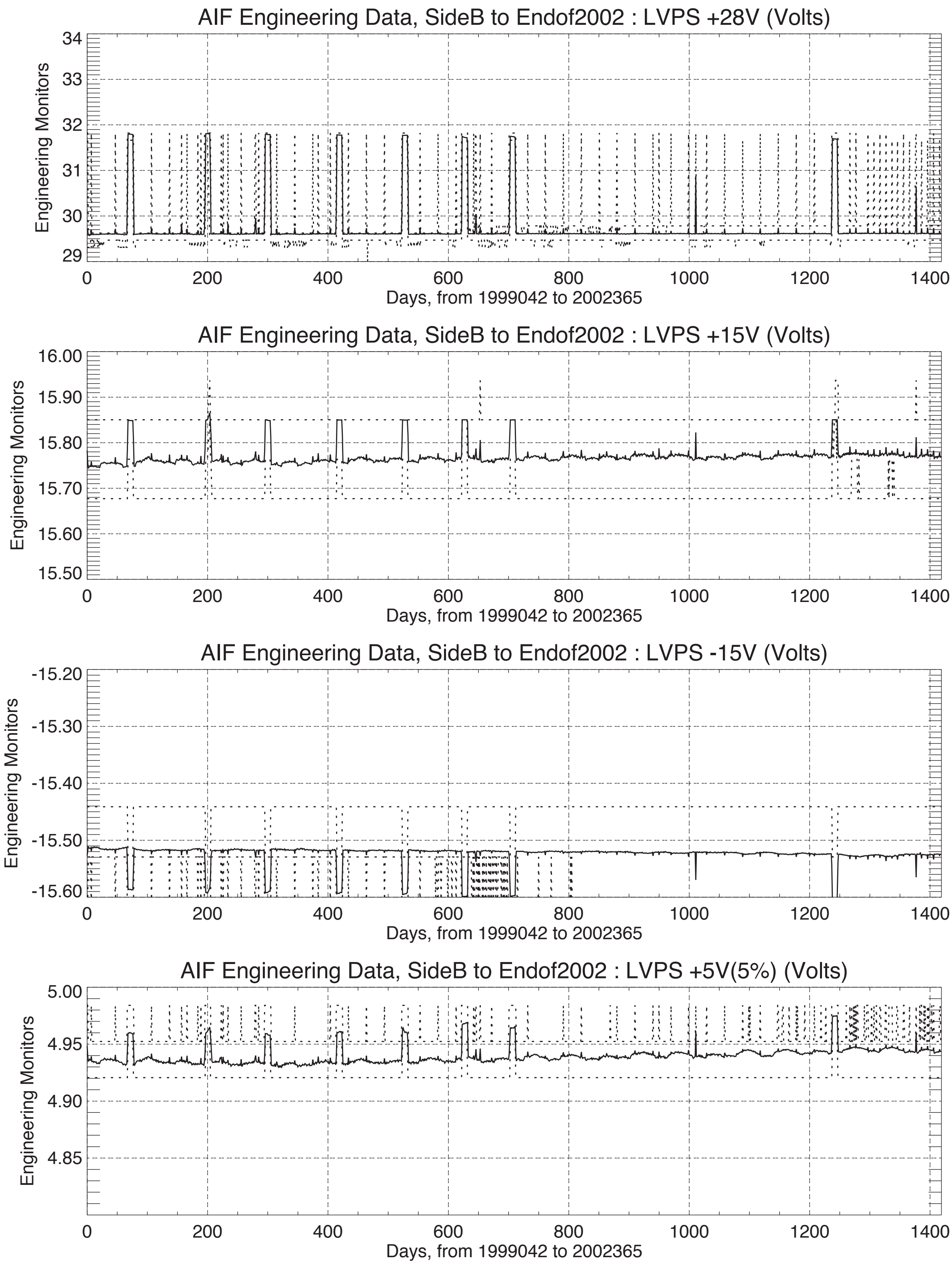

Figure 2-15 Engineering Monitor Histories (Continued)

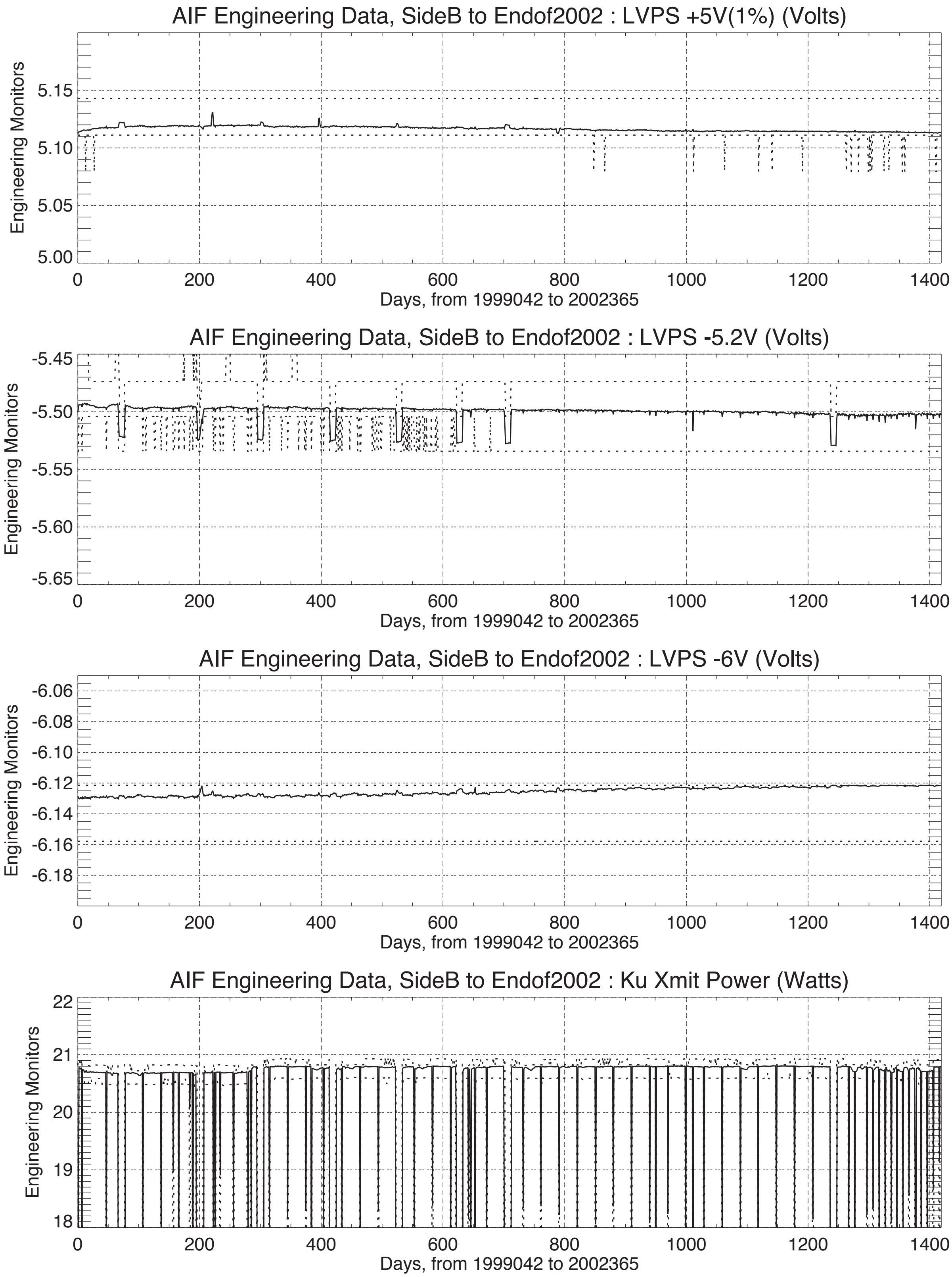

Figure 2-15 Engineering Monitor Histories (Continued)

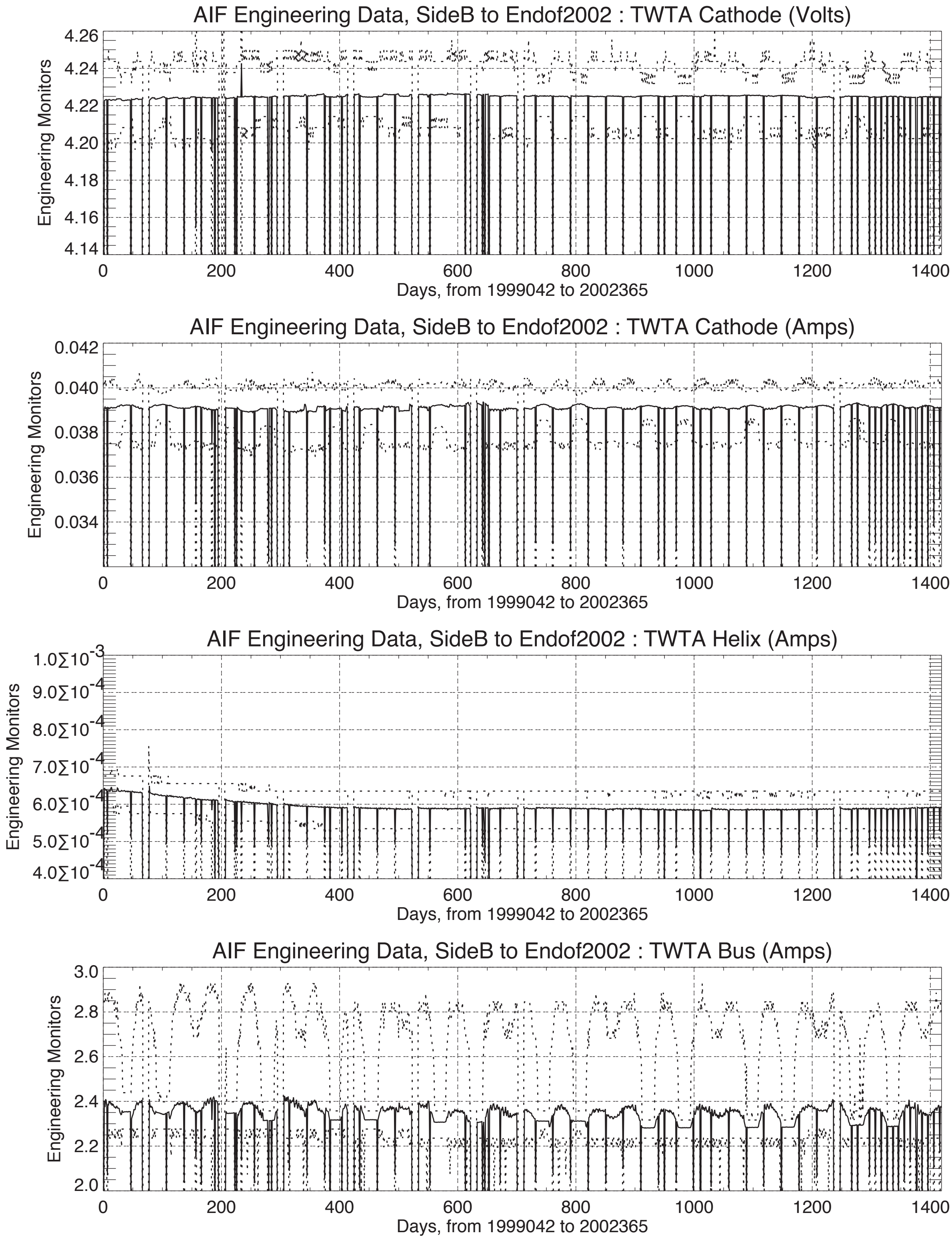

Figure 2-15 Engineering Monitor Histories (Continued)

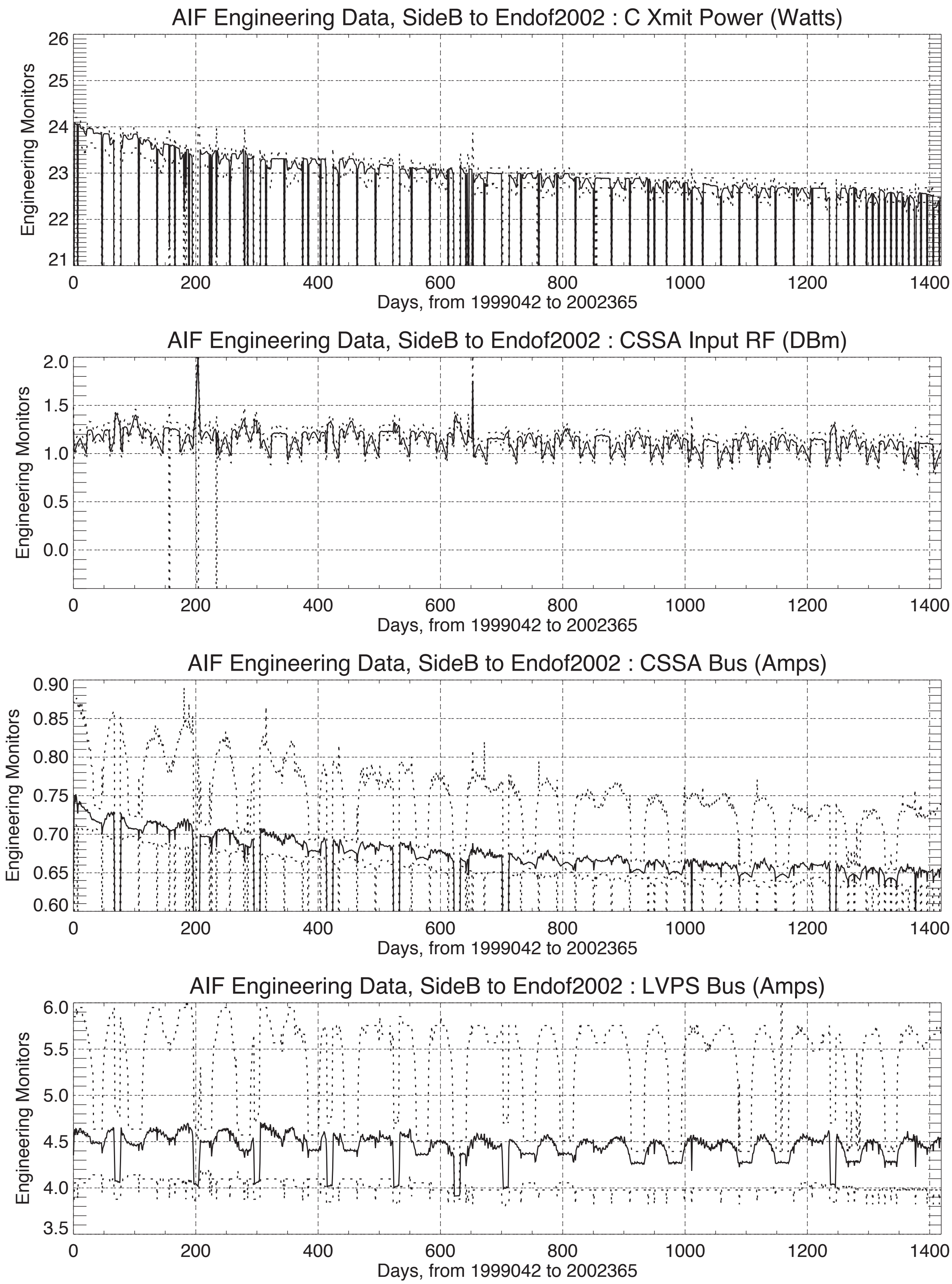

Figure 2-15 Engineering Monitor Histories (Continued)

As noted in previous years' assessment reports, the DCG Gate Array temperature is about 30 degrees higher than that experienced during pre-launch testing. Further, the temperature has exhibited a slow rise since Side B turn-on of about one degree per year, as noted by Beth Fabinsky of JPL. A lifetime thermal analysis of a similar DCG Gate Array unit indicates there still should be no great concern.

Although not used during our routine monitoring, several of the altimeter-related baseplate temperature monitors serviced by Remote Interface Unit (RIU) 6B became uncalibrated on day 17 of 1995. The affected temperature monitors are listed in Section 2.2.6.1 of the 1996 Engineering Assessment Report. An abrupt change in the values occurred on that date, apparently due to a change in the current which is applied to the thermistor circuits.

2.2.6.2 Voltages, Powers and Currents

The altimeter's 17 monitors for voltages, powers and currents remained at consistent levels, with little deviations. Their Side B to end of 2000 histories are also shown in Figure 2-15 "Engineering Monitor Histories" on page 2-17.

The eight voltages [LVPS +12V, LVPS +28V, LVPS +15V, LVPS -15V, LVPS +5V(5%), LVPS +5V(1%), LVPS -5.2V and LVPS -6V], have changed very little since Side B turn-on.

The following changes since turn-on of Side B are noted:

- The TWA Helix current has decreased about 0.05 milliamperes.
- The C-Band Transmit Power has decreased approximately 1.6 watts since turn-on.
- There has been a gradual decrease in the CSSA Bus current level; the level has decreased 0.10 amp since turn-on.

2.2.7 Single Event Upsets

There have been a total of 222 Single Event Upsets (SEUs) from the initial turn-on of Side B to the end of 2002, an average of one SEU per 6.3 days. The vast majority of the SEUs occurred in the South Atlantic Anomaly, as shown in Figure 2-16 "Locations of SEU Occurrences" on page 2-29. The dots in Figure 2-16 denote the locations of normal SEU occurrences, while the diamonds indicate that the SEU was abnormal.

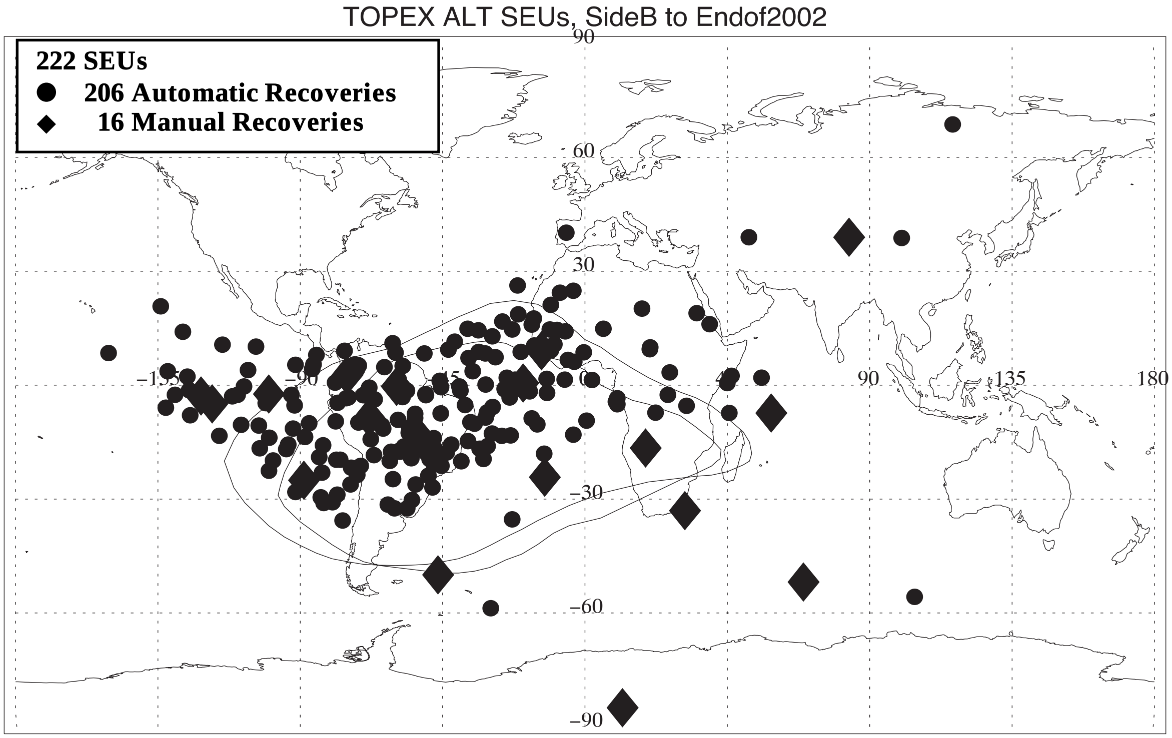

Figure 2-16 Locations of SEU Occurrences

The altimeter processor automatically recovered from 207 of the SEUs; the other 15 required manual (ground-based command) resets. The automatic resets, generally, each resulted in the loss of only a few seconds of data.

As of January 1, 2003, there have been a total of 23 anomalous Side B resets (the 15 manual resets plus 8 additional abnormal automatic resets). Table 2-1 lists the dates of these 23 SEUs, along with the type of on-board reset and the duration of the effect on the data.

Regarding the abnormal automatic reset in 2002:

- Day 2002-039 - The Flight Software was corrupted. The altimeter reset itself.

Table 2-1 Anomalous Single Event Upsets

Year	Day	Duration (Hr)	Reset Type	Type SEU
Side B				
1999	071	0.7	Manual	DFB Interface Lockup
1999	198	5.6	Manual	C MTU Xmit
1999	223	1.6	Manual	Memory Corrupted
1999	246	13.0	Manual	Eng. Interface Lockup
1999	276	3.1	Manual	Ku MTU Xmit
1999	280	0.1	Automatic	No waveform update/Range Sweep
2000	056	0.1	Automatic	Eng. Spare Word Corrupted
2000	067	5.8	Manual	Sci. Telemetry Lockup
2000	157	1.9	Manual	DFB Interface Lockup
2000	227	1.4	Manual	Sci. Telemetry Lockup
2000	275	1.1	Manual	DFB Interface Lockup
2001	070	0.1	Automatic	No WF Update
2001	079	1.3	Manual	Sci Telemetry Lockup
2001	112	1.3	Manual	DFB Interface Lockup
2001	166	0.1	Automatic	No WF Update
2001	173	3.2	Manual	DFB Interface Lockup
2001	205	3.0	Manual	DFB Interface Lockup
2001	217	6.5	Manual	Sci. Telemetry Lockup
2001	306	0.1	Automatic	No WF Update
2002	006	2.8	Manual	DFB Interface Lockup
2002	039	1.4	Automatic	Flt SW Corruption
2002	287	0.0	Manual	Bad Data - False Alarm
		Total = 54.2 Hrs		

2.3 Side B Key Events

The key events for TOPEX Altimeter Side B since its on-orbit turn-on are summarized in Table 2-2 "NASA Altimeter Side B - Key Events".

Table 2-2 NASA Altimeter Side B - Key Events

Day	Event
1999/041	Commanded Side B to IDLE Mode and Uploaded Memory Patches
1999/042	Commanded Side B to STANDBY and then to TRACK Mode
1999/042	Side B Testing, including: Mode Checks, Cal-Sweep, and Waveform Leakage Tests
1999/043	Additional Testing, including: Cal-Sweep, Waveform Leakage Tests, and Gate-Shift Tests
1999/048	Gate Shift Tests (lost 3.1 hours of data)
1999/049	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/049-050	Off-Nadir Tests
1999/050	Began First Side B Operational Cycle [Cycle 237]
1999/071	Improper SEU Recovery (lost 0.7 hours of data)
1999/089	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/109	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/109	Changed to IDLE Mode for SSALT
1999/119	Returned to TRACK Mode
1999/119	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/149	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/179	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/198-199	C-Band Autonomously Switched to Side A Transmit (lost 5.6 hours of data)
1999/209	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/223	C-Band CAMPIN Autonomously Disabled (lost 1.6 hours of data). Some corruption of Non-Protected Memory
1999/226	Unsuccessful Restoration of Non-Protected Memory, due to Command Table Error (lost 0.6 hours of overland data)

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
1999/231	Successful Restoration of Non-Protected Memory (lost 1.1 hours of mostly overland data)
1999/236	Commanding for New Parameter File, to Increase AGC Minimum from 13 to 15 dB (lost 0.1 hours of overland data).
1999/237	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/238	Changed to IDLE Mode for SSALT
1999/243	Spacecraft Safehold, after a reset of central data processing unit. ALT was automatically turned OFF.
1999/243	Commanded ALT back to IDLE Mode. Total OFF time was 15.7 hours.
1999/244	Uploaded full memory dump command. ALT remains in IDLE.
1999/245	ALT turned OFF during Attitude Control Electronics switchover
1999/246	Commanded ALT back to IDLE Mode and Uploaded full memory dump command. ALT remains in IDLE. OFF time was 7.9 hours.
1999/248	Returned to TRACK Mode
1999/252	Digital Filter Bank Calibration (lost 0.3 hours of overland data)
1999/265	Sent Commands in Attempt to Improve Acquisition. Lost 1.1 hours of land and ocean data. Commanding was Unsuccessful.
1999/268	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/276	Ku-Band Autonomously Switched to Side A Transmit (lost 3.1 hours of data)
1999/298	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/327	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/337	Changed to IDLE Mode for SSALT
1999/347	Returned to TRACK Mode
1999/357	Cal-Sweep Test (lost 0.4 hours of overland data)
1999/360	SEU resulted in corruption of the engineering Pass Count value. No apparent effect on ALT science data.
2000/012	Orbital Maneuver #13 (affected 1.2 hours of data)
2000/022	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/036	Digital Filter Bank Calibration (lost 0.3 hours of overland data)

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
2000/052	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/056-061	SEU at 056/141130 UTC resulted in corrupted engineering spare word. Memory reload on 061/070828 UTC corrected problem. ALT science data quality during the interim was apparently not affected.
2000/061	Reloaded memory to rectify engineering memory corruption which began on day 056. Lost 0.9 hours of mostly overland data. This memory reload also restored the engineering Pass Count value which had been corrupted by an earlier SEU on 1999/360.
2000/067	Improper SEU recovery (lost 5.8 hours of data)
2000/081	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/091	Changed to IDLE Mode for SSALT
2000/101	Returned to TRACK Mode
2000/111	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/141	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/157	Improper SEU recovery (lost 1.9 hours of data)
2000/171	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/200	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/200	Changed to IDLE Mode for SSALT
2000/210	Returned to TRACK Mode
2000/227	Improper SEU recovery (lost 1.4 hours of data)
2000/230	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/260	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/275	Improper SEU recovery (lost 1.1 hours of data)
2000/290	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/299	Changed to IDLE Mode for SSALT
2000/309	Returned to TRACK Mode
2000/319	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/322	Changed to IDLE Mode for Leonid Meteor Shower (lost 2.0 hours of data)

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
2000/329	Spacecraft Safehold, ALT was automatically turned OFF due to bad ephemeris load.
2000/330	Commanded Alt back to Track. Total off time was 27.1 hours.
2000/349	Cal-Sweep Test (lost 0.4 hours of overland data)
2000/352	Attitude Excursion to about 0.21 degrees for about 2000 seconds
2001/012	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/013	Changed to IDLE Mode for SSALT
2001/023	Returned to TRACK Mode
2001/036	The 'non-nominal' switch to Yaw Steering was caused by an OBC Euler-C Flag not being reset following the bad ephemeris load and Safehold of 11/23/00. (Flag was not reset due to an erroneous reinitialization command file). Lost 0.4 hours of data.
2001/043	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/070	Improper SEU recovery (lost 0.02 hours of data)
2001/072	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/079	Improper SEU recovery (lost 1.33 hours of data)
2001/101	Digital Filter-Bank Leakage Test and Transmit Test (lost 0.9 hours of data)
2001/102	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/112	Improper SEU recovery (lost 1.30 hours of data)
2001/132	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/162	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/166	Improper SEU recovery (lost 0.01 hours of data)
2001/173-174	Improper SEU recovery (lost 3.23 hours of data)
2001/191	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/205	Improper SEU recovery (lost 3.00 hours of data)
2001/217	Improper SEU recovery (lost 6.45 hours of data)
2001/221	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/251	Cal-Sweep Test (lost 0.4 hours of overland data)

Table 2-2   NASA Altimeter Side B - Key Events (Continued)

Day	Event
2001/258-261	SEU at 258/175123 UTC resulted in corrupted science spare word. Memory reload started on 261/035412 UTC corrected problem. ALT science data quality during the interim was apparently not affected.
2001/261	Reloaded memory to rectify science memory corruption which began on day 258. Lost 0.72 hours of mostly overland data.
2001/281	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/310	Cal-Sweep Test (lost 0.4 hours of overland data)
2001/322	Changed to IDLE Mode for Leonid Meteor Shower (lost 17.0 hours of data)
2001/340	Cal-Sweep Test (lost 0.4 hours of overland data)
2002/005	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/020	**Failed Digital Filter-Bank Leakage Test (lost 1.8 hours of data)**
2002/035	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/064	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/094	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/124	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/154	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/183	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/183	**Changed to IDLE Mode for SSALT**
2002/193	**SSALT seu prevented transmit power enable (lost 0.5 hours of data) during a transition from SSALT to ALT. Returned to TRACK Mode**
2002/213	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/223	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/227	**Start TOPEX Orbit Transfer Maneuver (TOTM). TOTM-D227, Burn 1 of 6.**
2002/231	**TOTM-D231, Burn 2 of 6.**
2002/233	**Cal-Sweep Test. ALT CAL-1 Sweep Test was unsuccessful due to data loss of 0.8 hours.**
2002/235	**TOTM-D235, Burn 3 of 6.**
2002/243	**Cal-Sweep Test (lost 0.4 hours of overland data)**

Table 2-2 NASA Altimeter Side B - Key Events (Continued)

Day	Event
2002/253	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/253	**TOTM-D253A & TOTM-D253B, Burn 4a & 4b of 6.**
2002/256	**TOTM-D256, Burn 5 of 6.**
2002/259	**Completed TOPEX Orbit Transfer Maneuver. TOTM-D259, Burn 6 of 6.**
2002/263	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/273	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/283	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/292	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/302	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/312	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/322	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/323	**Changed to IDLE Mode for Leonid Meteor Shower (lost 13.0 hours of data)**
2002/332	**Cal-Sweep Test (lost 0.4 hours of overland data)**
2002/342	**Cal-Sweep Test (lost 0.4 hours of overland data). ALT CAL-1 Sweep Test was invalidated by an [erroneously-scheduled] ALT calibration command file.**
2002/352	**Cal-Sweep Test (lost 0.4 hours of overland data).**
2002/362	**Cal-Sweep Test (lost 0.4 hours of overland data).**

Note: The key events since last update are indicated in **bold** type.

The listing of key events includes CalSweeps. In response to the altimeter's PTR change during Side A, a CalSweep software patch was developed, and was uploaded on day 250 of 1998. The purpose of this patch is to monitor the shape of the altimeter's CAL-1 waveform, looking for changes over time. Until day 223 of 2002, CalSweeps were regularly performed every 30 days, beginning with Side A on day 251 of 1998. Beginning with day 223, CalSweeps have been performed every 10 days in an effort to better understand the recent observed irregular CAL-1 Ku-Band range oscillations.The results of the Side B CalSweeps are discussed in Section 3.3.

2.4 Side B Abnormalities

2.4.1 Land-to-Water Acquisition Times

Early in the Side-B Mission, there were occasional slow land-to-water acquisition times, first reported in Section 2.6 of the “TOPEX Radar Altimeter Engineering Assessment Report, Update: Side B Turn-On to January 1, 2000.” The anomaly affected only about 0.02% of the potentially available ocean data; it was last observed on day 243 of 1999.

Since that time, and throughout the year 2002, we have monitored the land-to-water acquisition times, and the anomaly has not recurred. We continue to monitor the acquisition times, and we continue to use the AGCMIN15 parameter file as our standard.

2.4.2 Attitude Anomaly

There were short-duration attitude excursion anomalies, with maximum attitudes near 0.2 degree, were initially reported in the "TOPEX Radar Altimeter Engineering Assessment Report, Update: Side B Turn-On to January 1, 2001" and again in the "TOPEX Radar Altimeter Engineering Assessment Report, Update: Side B Turn-On to January 1, 2002".

During the year 2002, there was a spike on day 2002-352, in conjunction with a maneuver yaw unwind (OMM23). Also during the year 2002, there was the TOPEX Orbit Transfer Maneuver (TOTM) on days 2002-227, 2002-231, 2002-235, 2002-253, 2002-256, and 2002-259. On each of these days, there was a spike that was in conjunction with a maneuver yaw unwind.

The range noise, the AGC, and the SWH values appear reasonable throughout the attitude anomalies. There should be no consequence to the TOPEX data users, due to the TOPEX off-nadir corrections during ground processing being valid for attitudes out to 0.4 degree.

Section 3

Assessment of Instrument Performance (Cycles 236 through 379)

3.1 Range

The following range discussion is restricted to TOPEX Side B, from its start at cycle 236 (which started on 1999 day 040) through cycle 379 which was the last cycle starting in year 2002 (cycle 379 started on 2002 day 362). Earlier years' assessment updates supplied cumulative results for Side A from launch to the end of the assessment update period, and the assessment update published in August 1999 provided the entire set of TOPEX Side A results from launch through Side A turnoff on 10 February 1999.

This report section discusses the Side B CAL-1 Step-5 Ku- and C-band delta ranges. The Calibration Mode was briefly reviewed in Section 2.1. The Ku- and C-band delta ranges have been processed to form a set of delta combined range values, where "combined" refers to the weighted sum of Ku- and C-band delta ranges which compensates for the ionospheric electron path delay. There are about twenty combined delta ranges for each TOPEX cycle, corresponding to two calibrations per day during the 10-day cycle. Early in Side A operation we developed a CAL-1 processing scheme to remove the effects of a 7.3 mm range quantization in the TOPEX internal calibration mode. The Side B is almost identical to Side A, the same calibration mode quantization is present in the CAL-1 delta range data, and we have used the same processing method to remove these quantization effects.

In previous years we had found that the Side A delta ranges had a temperature dependence. There are about two dozen different temperatures monitored within the TOPEX altimeter, and it is not possible to determine which of these is the most important to range bias. For our Side A analysis we had used the temperature of the upconverter / frequency multiplier unit (the UCFM), designating this temperature as Tu. The Ku-band delta range and the combined delta range varied somewhat with Tu, and we had found a simple quadratic correction of the combined delta range for Tu variation. Our previous years' assessment updates had tables of the range bias results with and without the correction for Tu, but we recommended that the TOPEX GDR data end user (who did not have easy access to the temperature data) should use the Side A combined delta range results that were NOT corrected for temperature Tu.

For Side B the behavior of delta range with temperature is somewhat different. We have found that the C-band result exhibited a temperature dependence more highly correlated with the receiver AGC temperature (designated Tagc here) than with Tu. Figure 3-1 shows the full-rate Side B Tagc values through the end of cycle 379, and Figure 3-2 shows full-rate Side B C-band CAL-1 Step 5 delta range values. Some of the "spikes" in the C-band delta range of Figure 3-2 can be removed by assuming a quadratic dependence of delta range on Tagc and doing a simple least-squares fit to find the coefficients for the quadratic dependence. Figure 3-3 on page 3-3 shows the

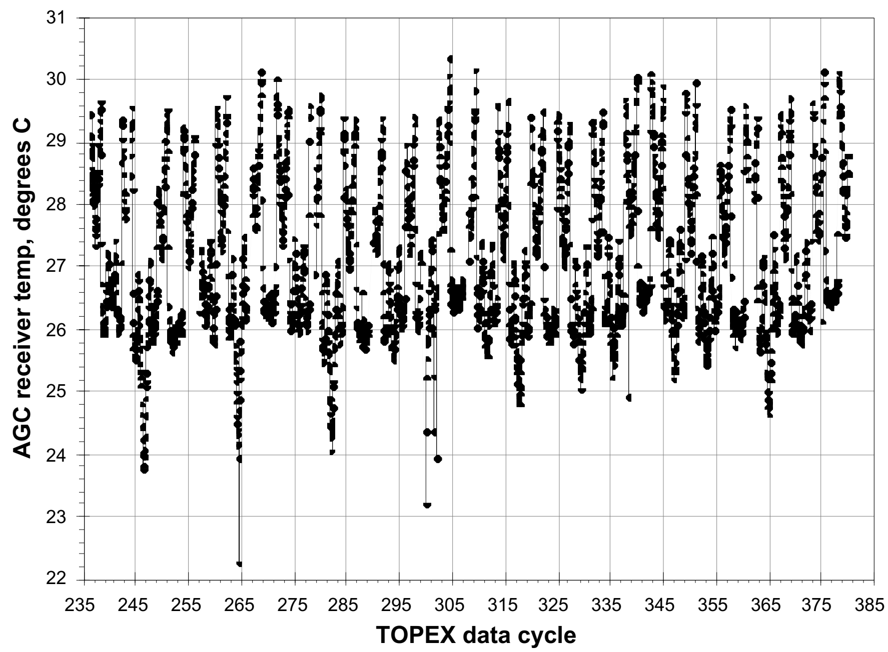

Figure 3-1 AGC Receiver Temperature *vs*. Data Cycle

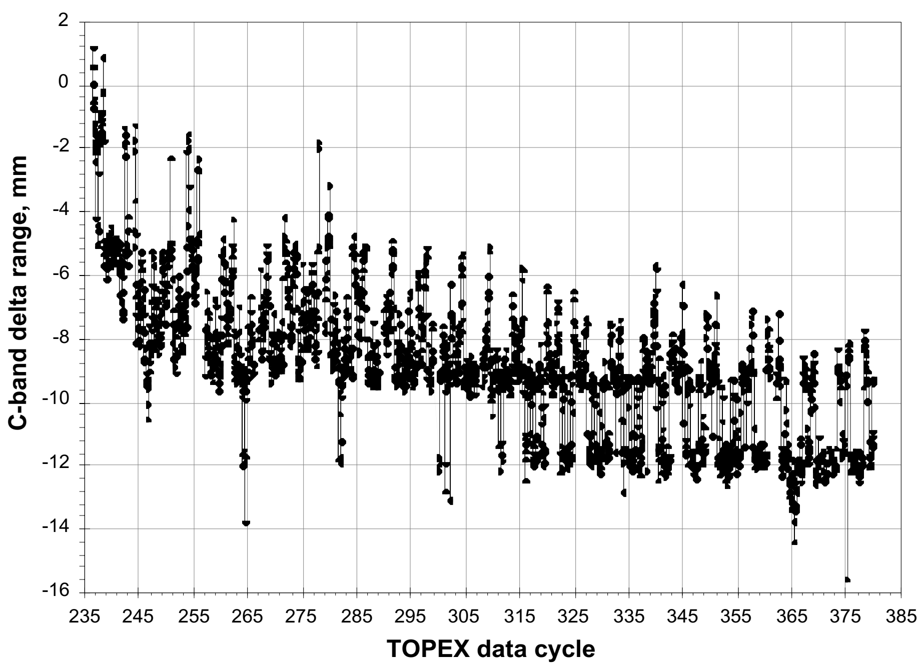

Figure 3-2 C-Band CAL-1 Step 5 Delta Range vs. Data Cycle, No Tagc Corrections

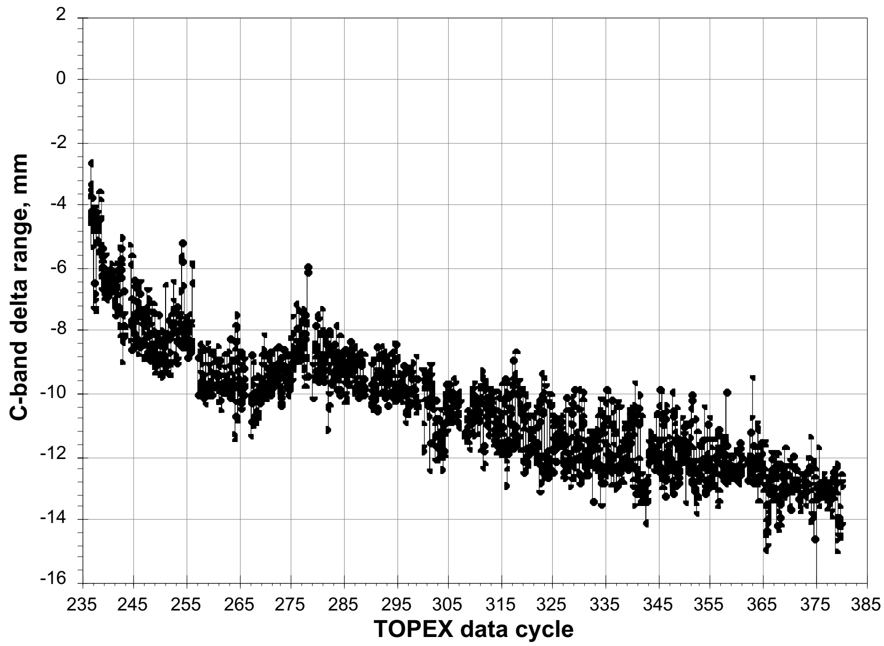

Figure 3-3 C-Band CAL-1 Step 5 Delta Range *vs*. Data Cycle After Tagc Corrections

Side B C-band delta range after making the quadratic correction for the Tagc, and it can be seen that the Tagc correction term does eliminate some of the variations of the individual data relative to the general trend.

Figure 3-4 on page 3-4 and Figure 3-5 on page 3-4 show the Side B Ku-band CAL-1 Step 5 delta range values for the same time span, before and after removing a quadratic correction for Tagc. It can be seen that the Tagc correction has a visible but small effect on the results. A surprising feature in Figure 3-4 and Figure 3-5 is the change of character of the Ku-band CAL-1 delta range which started early in cycle 364; from that time there is an increased "meandering" of the Ku-band delta range which persists through the time of this report's writing. We do not know the reason for his change in TOPEX Side B Ku-band CAL-1 delta range behavior, and cannot correlate this with any of the temperatures, voltages, and powers available in the TOPEX engineering telemetry. More discussion of the Ku CAL-1 range meandering is available in Appendix B. We will not discuss it further in this section except to note that all the Tagc corrections to CAL-1 ranges are based on fits to the results from cycles 236 through 363, the "normal" period before the meandering started.

Figure 3-6 on page 3-5 and Figure 3-7 on page 3-5 compare the Side B combined delta range results before and after Tagc corrections, and the Tagc corrections have little discernible effect. Because the combined delta range is a weighted sum of the Ku- and C-band ranges, with relative weights of approximately +7/6 and -1/6, the combined range shows meandering similar to the Ku-band range.

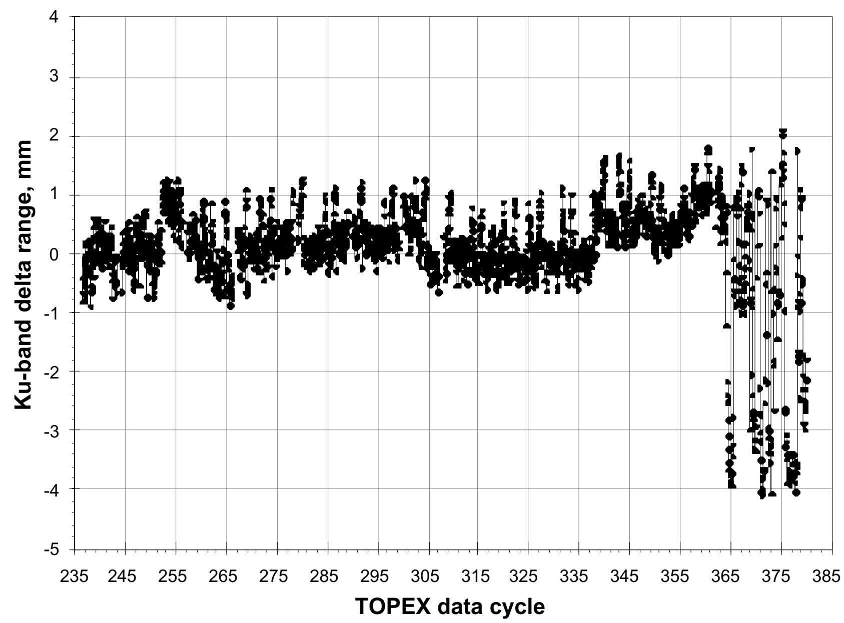

Figure 3-4 Ku-Band CAL-1 Step 5 Delta Range vs. Data Cycle, No Tagc Corrections

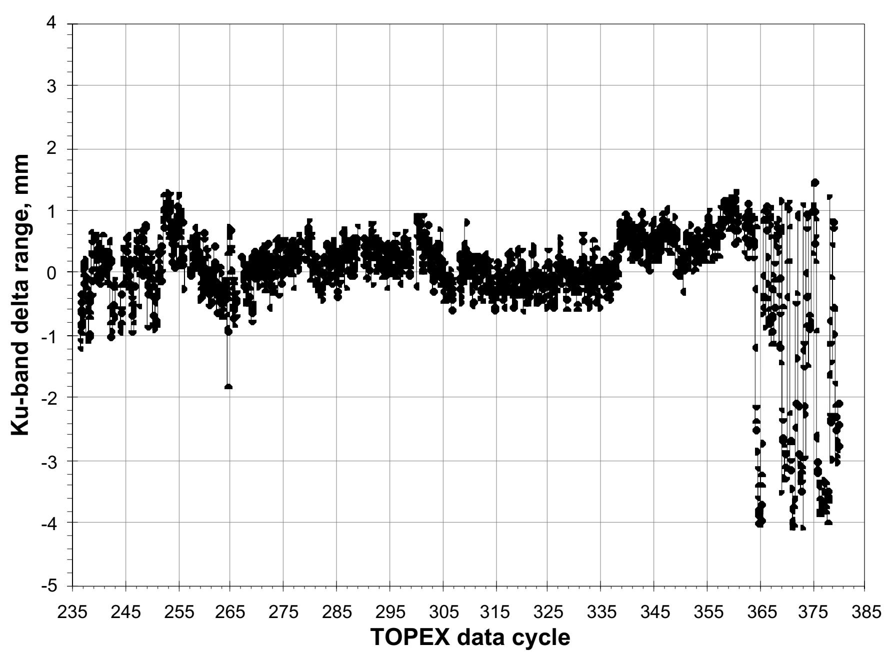

Figure 3-5 Ku-Band CAL-1 Step 5 Delta Range *vs*. Data Cycle After Tagc Corrections

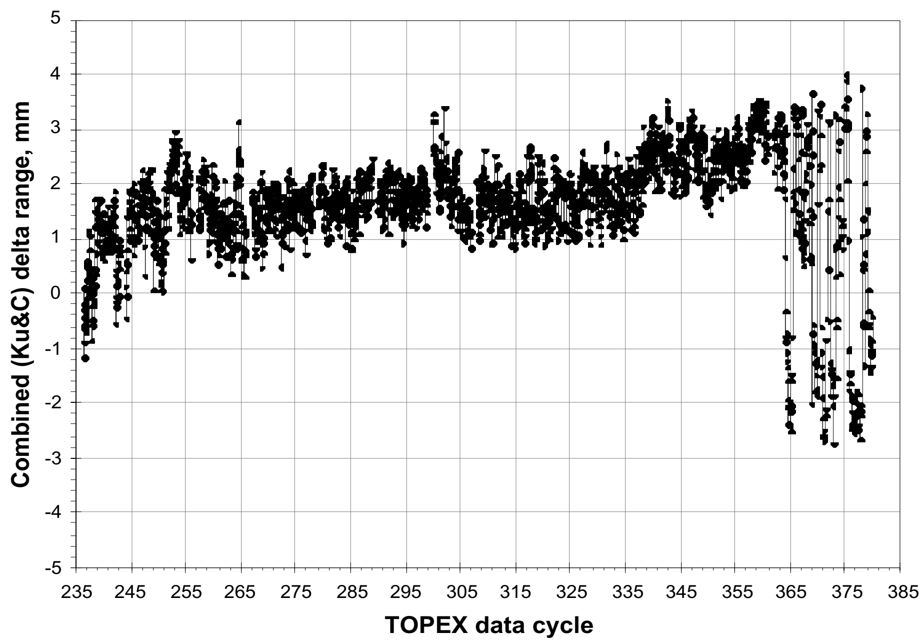

Figure 3-6 Ku- & C-Band Combined CAL-1 Step 5 Delta Range *vs*. Data Cycle, No Tagc Corrections

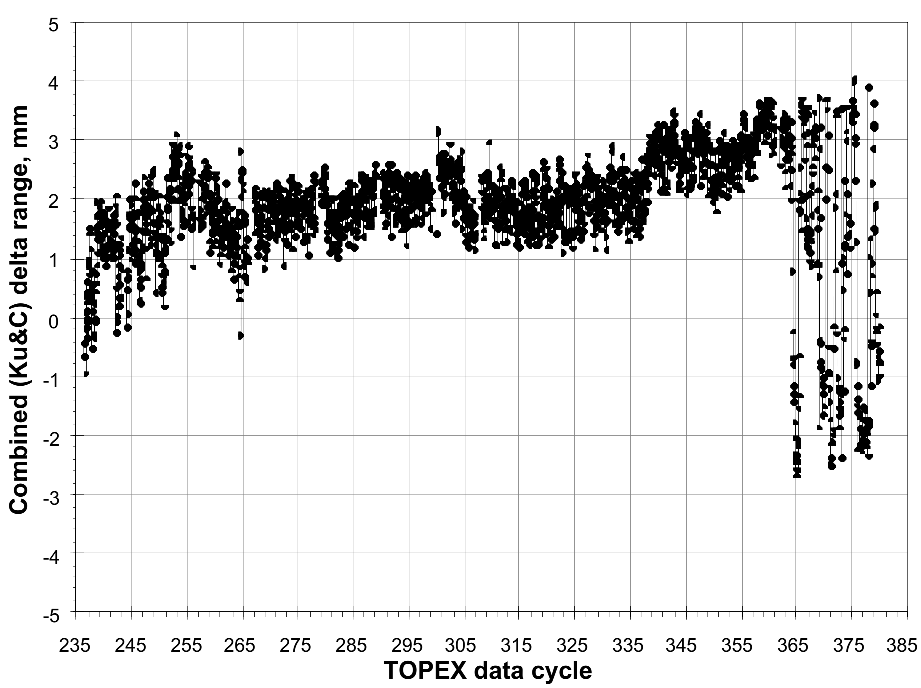

Figure 3-7 Ku- & C-Band Combined CAL-1 Step 5 Delta Range *vs*. Data Cycle After Tagc Correction

As for Side A, the general trend of delta ranges until cycle 364 is slow enough that corrections can and should be made based on cycle averages of the cal-based delta ranges; after cycle 364 we do not know how to deal with the meandering delta height, so will continue with cycle-averages for now. Figure 3-8 and Figure 3-9 show

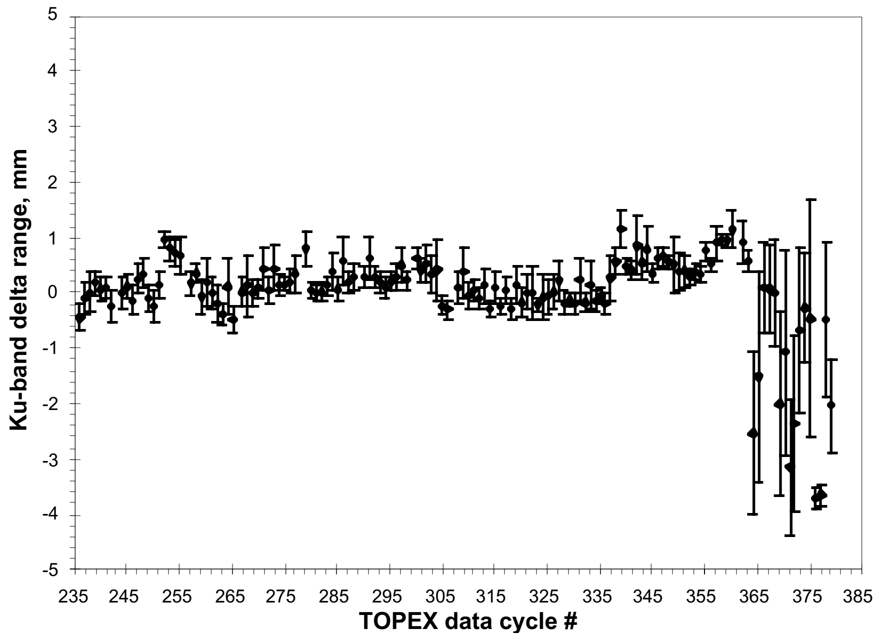

Figure 3-8 Ku-Band Cycle-Averaged Delta Range *vs*. Data Cycle, No Tagc Corrections

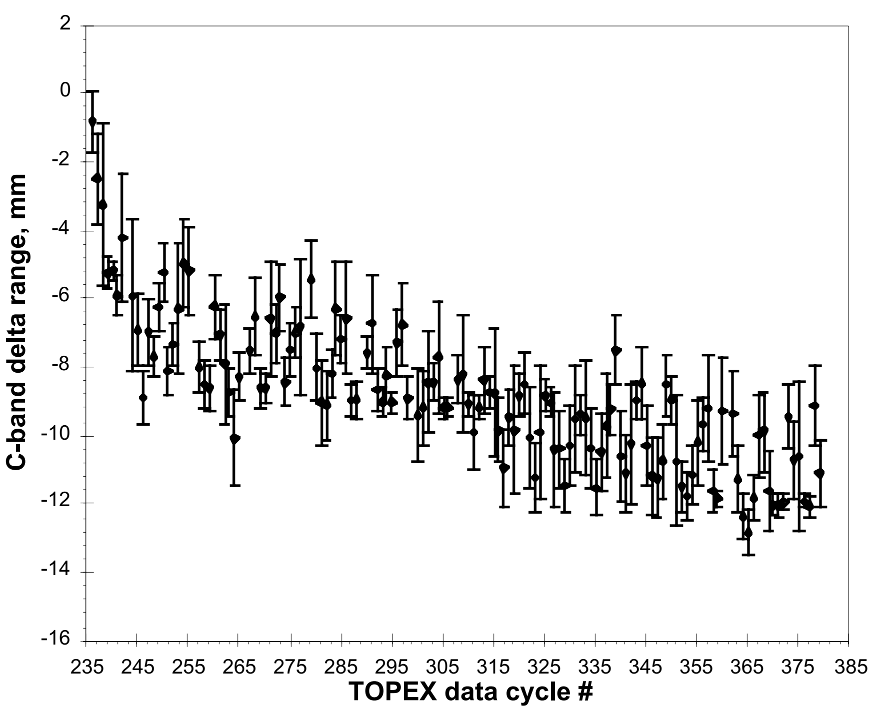

Figure 3-9 C-Band Cycle-Averaged Delta Range *vs*. Data Cycle, No Tagc Corrections

the Side B Ku- and C-band cycle averages of the delta height with no Tagc temperature correction applied. Figure 3-10 shows the set of cycle averages of the combined

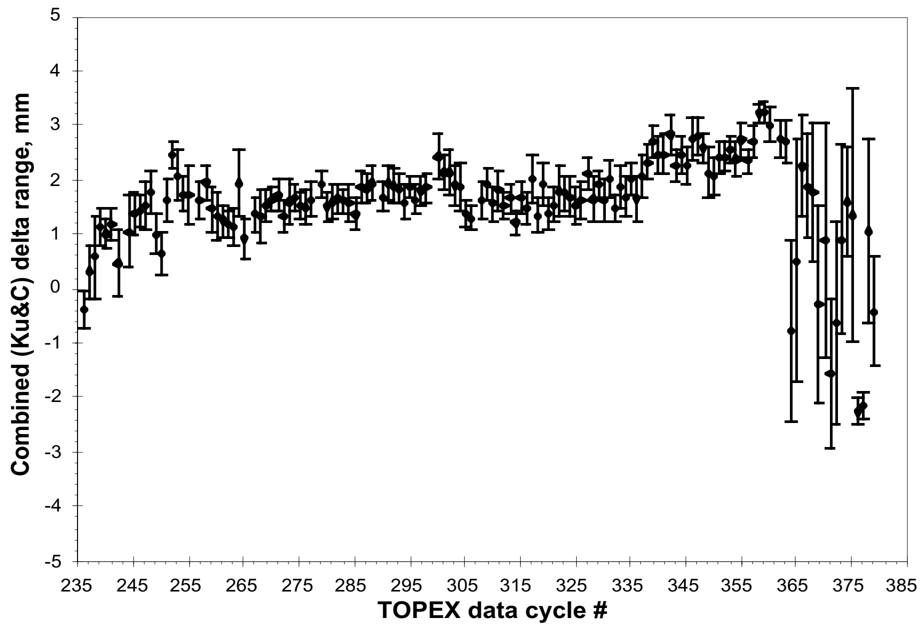

Figure 3-10 Ku- & C-Band Combined Cycle-Averaged Delta Range *vs*. Data Cycle, No Tagc Corrections

height delta ranges with no temperature correction, and Figure 3-11 shows the cycle

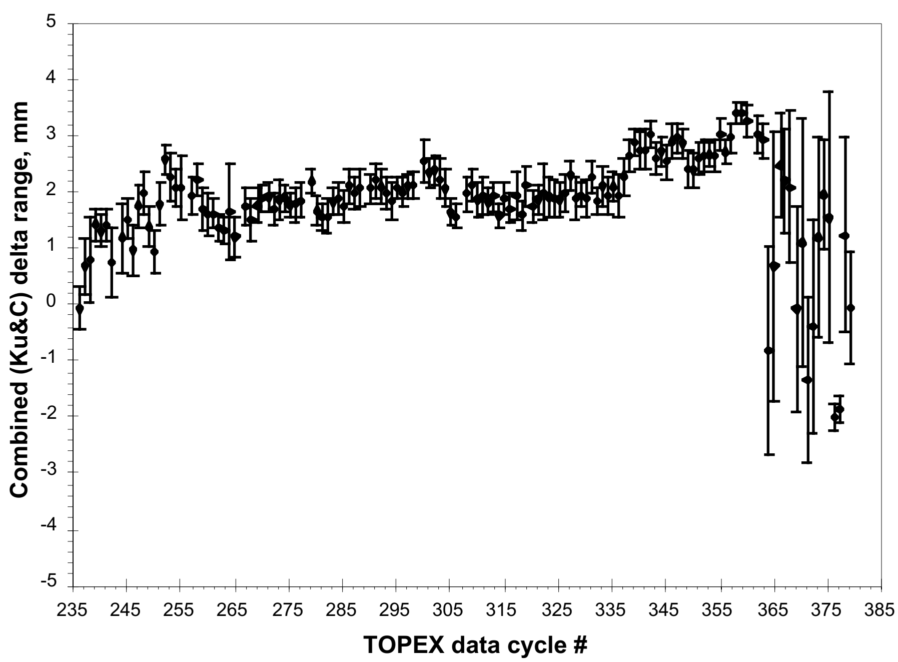

Figure 3-11 Ku- & C-Band Combined Cycle-Averaged Delta Range *vs*. Data Cycle After Tagc Corrections

averages of combined delta ranges WITH the Tagc correction.There is no apparent benefit to using the Tagc correction for the combined delta range, and we strongly recommend using the Side B combined delta ranges with NO temperature correction, and these values are printed in Table 3-1.

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5 (No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
001	15	+2.795	1.691
002	18	+1.867	0.644
003	18	+2.527	1.191
004	18	+1.811	0.929
005	20	+1.947	0.808
006	20	+1.792	0.975
007	14	+1.602	0.178
008	18	+1.799	0.194
009	17	+1.751	0.661
010	20	+1.594	0.253
011	20	+1.342	0.500
012	19	+1.645	0.757
013	15	+1.622	0.236
014	17	+1.941	0.532
015	19	+1.985	0.474
016	20	+2.060	0.461
017	21	+1.723	0.319
018	18	+1.484	0.223
019	16	+1.615	0.151
021	20	+2.047	0.149
022	20	+1.672	0.205
023	19	+1.354	0.355
024	21	+0.624	0.289
025	20	+0.553	0.545
026	19	+1.517	0.155
027	20	+1.517	0.131
028	20	+1.131	0.217
029	20	+0.614	0.255
030	18	+0.924	0.372
032	18	+1.727	0.397
033	17	+0.805	0.869
034	20	+0.023	0.152
035	18	-0.490	0.606
036	20	-0.777	0.667
037	18	+0.283	0.482
038	19	+0.734	0.322
039	20	+0.834	0.406
040	21	+0.690	0.419
042	20	-0.609	0.536
043	19	-0.081	0.240
044	17	+0.152	0.227
045	20	+0.170	0.223
046	19	-0.316	0.655

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5 (No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
047	19	-1.348	0.334
048	19	-0.148	0.588
049	18	-0.165	0.421
050	19	+1.349	0.603
051	20	-0.076	0.723
052	20	-0.183	0.270
053	20	-1.823	0.666
054	21	-0.810	0.702
056	20	-0.435	0.715
057	20	-1.059	0.418
058	20	-0.957	0.323
059	20	-2.053	0.580
060	20	-2.299	0.543
061	19	-1.569	0.236
062	20	-1.455	0.157
063	20	-1.392	0.158
064	21	-2.245	0.554
066	20	-1.488	0.154
067	19	-1.843	0.400
068	20	-0.302	0.639
069	20	-2.039	0.472
070	20	-2.554	1.102
071	20	-3.780	0.575
072	20	-4.598	1.804
073	19	-2.411	0.518
074	20	-2.742	0.410
075	20	-3.112	0.595
076	19	-2.598	0.483
077	19	-3.883	0.374
078	20	-3.715	0.444
080	19	-3.059	0.350
081	20	-3.526	0.300
082	20	-5.491	1.251
083	20	-4.814	0.724
084	20	-3.976	0.258
085	20	-3.276	1.038
086	20	-1.596	1.172
087	20	-4.199	0.212
088	21	-4.296	0.252
089	20	-4.434	0.327
090	20	-4.181	0.262
092	19	-3.524	0.172
093	20	-3.732	0.244
094	20	-3.918	0.273
095	20	-4.374	0.294
096	19	-4.268	0.248
098	19	-3.373	0.152
099	20	-3.528	0.161
100	19	-3.759	1.072

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5
(No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
101	20	-4.003	0.232
102	20	-3.895	0.161
104	20	-2.646	1.185
105	20	-3.457	0.213
106	20	-3.779	0.499
107	20	-4.509	0.207
108	19	-3.955	0.196
109	19	-3.808	0.168
110	20	-3.705	0.252
111	20	-3.727	0.143
112	20	-4.028	0.351
113	20	-4.251	0.202
115	17	-3.092	0.336
116	20	-3.045	0.295
117	16	-3.191	0.299
118	2	-1.832	3.533
119	17	-5.211	1.013
120	20	-4.668	0.454
121	19	-3.735	0.675
122	20	-4.013	0.622
123	13	-4.242	0.658
124	20	-4.758	0.797
125	21	-4.860	0.574
127	19	-3.726	0.617
128	20	-3.983	0.310
129	20	-3.722	0.214
130	20	-4.125	0.783
131	20	-2.970	0.615
132	19	-2.120	0.172
133	20	-1.948	0.127
134	20	-1.764	0.184
135	20	-2.604	0.710
136	20	-2.878	0.371
137	21	-1.968	0.904
139	20	+0.712	0.893
140	20	-1.252	0.839
141	20	-1.464	0.285
142	20	-2.613	0.539
143	19	-2.626	0.558
144	18	-1.490	0.210
145	21	-1.980	0.377
146	20	-1.569	0.408
147	19	-1.736	0.341
148	18	-3.065	0.336
149	20	-2.741	0.630
151	20	-1.701	1.027
152	20	-1.737	0.208
153	20	-2.548	0.751
154	20	-2.961	0.288

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5
(No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
155	20	-2.214	0.683
156	19	-1.607	0.511
157	20	+0.794	0.815
158	20	-1.144	0.562
159	20	-1.162	0.776
160	20	-2.779	0.385
161	21	-2.641	0.886
163	19	-1.277	0.296
164	20	-0.881	0.186
165	20	-2.058	1.000
166	20	-2.405	0.241
167	20	-1.566	0.707
168	19	-0.960	0.235
169	20	-1.283	0.219
170	20	-0.935	0.159
171	21	-1.454	0.400
172	20	-1.447	0.453
173	20	-0.380	0.227
175	16	+1.732	0.436
176	20	+0.317	0.346
177	21	+0.428	0.383
178	20	-0.382	0.186
179	20	+0.148	0.671
181	19	+1.211	0.886
182	20	+1.084	0.150
183	20	+0.556	0.510
184	19	+0.142	0.253
185	20	+0.616	0.170
187	20	+0.845	0.719
188	20	+0.638	0.242
189	20	+0.183	0.410
190	20	+0.302	0.348
191	20	+0.898	0.213
192	20	+1.983	1.237
193	20	+3.390	1.249
194	17	+1.498	0.814
195	19	+1.046	0.888
196	18	+0.543	0.504
198	19	+2.804	0.583
199	19	+2.757	0.229
200	20	+2.735	0.224
201	20	+1.946	0.222
202	19	+2.042	0.302
203	18	+2.720	0.419
204	17	+2.915	0.220
205	20	+3.023	0.269
206	19	+3.051	0.640
207	19	+3.062	0.652
208	20	+3.043	0.689

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5
(No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
210	17	+5.088	0.196
211	15	+4.662	0.297
212	20	+4.712	0.365
213	20	+3.015	0.603
214	20	+3.668	0.389
215	21	+3.534	0.862
217	20	+4.867	0.356
218	20	+3.684	0.759
219	19	+4.089	0.307
220	19	+3.935	0.655
221	19	+5.502	0.294
222	20	+5.536	0.254
223	20	+5.537	0.291
225	20	+4.867	0.407
226	19	+4.488	0.733
227	21	+5.880	0.332
228	21	+6.780	0.662
229	20	+6.738	0.591
230	20	+6.430	0.594
231	20	+5.453	0.591
232	20	+5.259	0.647
233	19	+6.365	0.897
235	18	+7.086	0.266
236	21	-0.373	0.351
237	21	+0.336	0.490
238	20	+0.599	0.755
239	19	+1.163	0.333
240	20	+1.019	0.284
241	20	+1.191	0.284
242	21	+0.480	0.609
244	20	+1.062	0.673
245	19	+1.388	0.386
246	20	+1.448	0.288
247	20	+1.554	0.445
248	20	+1.793	0.398
249	20	+1.018	0.368
250	20	+0.657	0.383
251	19	+1.637	0.408
252	19	+2.460	0.256
253	20	+2.088	0.472
254	22	+1.749	0.328
255	21	+1.749	0.530
257	18	+1.649	0.346
258	20	+1.956	0.304
259	20	+1.473	0.400
260	20	+1.339	0.431
261	20	+1.269	0.292
262	20	+1.201	0.264
263	19	+1.135	0.338

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5 (No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
264	21	+1.950	0.599
265	20	+0.929	0.356
267	20	+1.383	0.327
268	20	+1.335	0.494
269	19	+1.541	0.317
270	20	+1.654	0.234
271	20	+1.716	0.297
272	21	+1.334	0.288
273	20	+1.605	0.409
274	20	+1.690	0.226
275	18	+1.530	0.248
276	19	+1.509	0.316
277	21	+1.651	0.317
279	20	+1.927	0.257
280	19	+1.513	0.283
281	19	+1.609	0.339
282	20	+1.665	0.273
283	19	+1.630	0.223
284	19	+1.596	0.351
285	20	+1.375	0.299
286	20	+1.868	0.301
287	18	+1.851	0.273
288	20	+1.951	0.325
290	20	+1.697	0.265
291	20	+1.953	0.332
292	20	+1.903	0.312
293	18	+1.856	0.275
294	20	+1.589	0.318
295	19	+1.882	0.210
296	19	+1.654	0.258
297	20	+1.817	0.255
298	18	+1.878	0.271
300	20	+2.442	0.399
301	23	+2.147	0.309
302	18	+2.149	0.428
303	19	+1.910	0.384
304	19	+1.882	0.423
305	19	+1.384	0.242
306	20	+1.301	0.216
308	20	+1.623	0.333
309	20	+1.924	0.307
310	19	+1.578	0.316
311	20	+1.830	0.365
312	20	+1.544	0.257
313	19	+1.678	0.267
314	20	+1.224	0.208
315	21	+1.691	0.310
316	19	+1.478	0.301
317	20	+2.027	0.459

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5
(No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
318	20	+1.358	0.315
319	20	+1.932	0.377
320	20	+1.393	0.292
321	19	+1.548	0.311
322	19	+1.803	0.483
323	19	+1.773	0.328
324	20	+1.697	0.362
325	20	+1.530	0.340
326	20	+1.651	0.348
327	19	+2.132	0.275
328	19	+1.657	0.428
329	20	+1.918	0.238
330	18	+1.633	0.379
331	20	+2.013	0.349
332	20	+1.488	0.256
333	20	+1.874	0.392
334	19	+1.692	0.372
335	20	+2.031	0.283
336	20	+1.662	0.406
337	20	+2.076	0.383
338	20	+2.330	0.318
339	20	+2.714	0.312
340	19	+2.484	0.342
341	20	+2.482	0.355
342	20	+2.844	0.356
343	19	+2.269	0.301
344	20	+2.462	0.345
345	20	+2.280	0.344
346	19	+2.750	0.389
347	20	+2.809	0.328
348	20	+2.598	0.283
349	20	+2.136	0.455
350	20	+2.073	0.347
351	20	+2.419	0.289
352	19	+2.433	0.255
353	20	+2.564	0.254
354	19	+2.393	0.296
355	19	+2.741	0.304
356	19	+2.353	0.201
357	19	+2.730	0.300
358	19	+3.231	0.190
359	20	+3.248	0.178
360	20	+3.018	0.329
362	19	+2.773	0.343
363	20	+2.720	0.386
364	19	-0.756	1.672
365	19	+0.522	2.218
366	20	+2.254	0.927
367	20	+1.893	0.963

Table 3-1 TOPEX Range Bias Changes Based on CAL-1 Step 5 (No Temperature Corrections)

Cycle #	Count	Avg dR (comb), mm	StDev dR (comb), mm
368	20	+1.788	1.285
369	16	-0.274	1.826
370	13	+0.901	2.143
371	12	-1.550	1.389
372	14	-0.620	1.844
373	15	+0.908	1.741
374	12	+1.614	1.014
375	16	+1.366	2.321
376	12	-2.247	0.238
377	14	-2.125	0.256
378	19	+1.072	1.682
379	19	-0.406	0.996

These values are also available at our TOPEX web site

http://topex.wff.nasa.gov/docs/RangeStabUpdate.html,

and that web site is updated every month or so. The web site table also has the delta ranges which are temperature corrected for Tu using the correction developed for Side A. It was incorrect to calculate the Side A correction for the Side B data on the web site, and the Tu correction should be ignored. The simple rule for Side B is to use the delta range that has NO temperature correction.

To correct the GDR range data for the range calibration drift, one would use

Corrected Range = GDR range - dR_av_N,

where dR_av_N is the cycle-average delta combined range value of Table 3-1(as plotted in Figure 3-9). Note that the delta ranges are all given relative to a constant but arbitrary range offset, so this correction will provide only a relative range drift correction. The corresponding expression for correcting the GDR sea surface height (SSH) is

Corrected SSH= GDR SSH + dR_av_N.

3.2 AGC/Sigma0

The ocean surface's radar backscattering cross section, one of the quantities estimated by the TOPEX radar altimeter, is designated by σ^0 which for typographical convenience is often referred to as sigma0 or sigma-naught; in this report section we will use sigma0. Most altimeters will eventually drift in their power estimation and hence in their sigma0 estimation. To correct for such drift, the TOPEX ground data processing includes a lookup table of sigma0 corrections. We will refer to that table as the "Cal Table" (the relevant TOPEX ground data processing system filename is SPA_ALT_CALPAR.TXT). In this section we describe the sigma0 trends from start of Side B (cycle 236) through cycle 379. Our sigma0 trend analyses use the sigma0 before the Cal Table corrections have been applied, and we refer to this as sigma0_uncorr or as uncorrected sigma0.

3.2.1 Processing of Calibration Mode Results and Global Sigma0 Averages

As part of our continuing TOPEX support, we do daily quick-look processing of all TOPEX altimeter data for performance monitoring, providing performance summaries for the engineering and science data. The daily processing results are used to update a launch-to-date engineering database. Also, data are processed from the twice-daily execution of the altimeter's internal calibration mode (with submodes CAL-1 and CAL-2) and these results are used to update a WFF launch-to-date calibration database. We also process the intermediate geophysical data record (IGDR) data as they become available for network access, normally several days after the altimeter acquires the data. The IGDR data are processed for altimeter performance, and 1-minute summary records are produced and are added to a WFF launch-to-date GDR database. When the final GDR data become available, they replace the IGDR data already in our database. There is no difference however between sigma0 data on the IGDR and the GDR, because no further sigma0 corrections are made in going from the IGDR to the GDR.

We have been very concerned about possible contamination of the data by what we have called "sigma0 blooms", regions of over-ocean altimeter data characterized by unusually high apparent sigma0 values accompanied by unusual altimeter waveform shapes. Generally the Ku-and the C-band sigma0 show the same behavior in a bloom region. Such blooms in the TOPEX data can persist for several tens of seconds, and the waveforms in a bloom region generally have too rapid a plateau decay. Many of these waveforms are too sharply peaked ("specular"), indicating a breakdown in the general incoherent scattering theory used to characterize the rough surface scattering. The sigma0 blooms exist in perhaps 5% of all TOPEX over-ocean data (there is additional sigma0 bloom information at http://topex.wff.nasa.gov/blooms/blooms.html). For input to our GDR database 1-minute averages, we require all the available altimeter flags to show normal tracking and the land/water flag to show deep water. When the data are extracted from this database for the sigma0 calibration, all records are rejected having Ku-band sigma0 estimates of 16 dB or greater or having waveform-estimated attitude angles of 0.12 degrees or greater. These editing criteria delete most of the sigma0 blooms.

Because our analysis is based on sigma0_uncorr, we need to know what Cal Table values have been already applied to the GDR (or IGDR) data in order to "undo" these corrections.

3.2.2 History of Cal Table Values Used in GDR Production

There were eighteen Cal Table adjustments during the TOPEX Side A operation. For Side B operation there have been eight additional Cal Table adjustments, to date, after the initial Side B Cal Table was set. There exists no single summary of exactly when each of the Cal Table changes was implemented in the TOPEX Side B ground processing so we will provide that summary here. The Side A Cal Table history has been described year by year in earlier Engineering Assessment Updates, and the entire Side A history is summarized at http://topex.wff.nasa.gov/docs/Sigma0Cal_A_All.pdf.

Each time that the Cal Table contents are changed in the TOPEX ground data processing at JPL, there are at least three items created within JPL's Mission Operations System (MOS):

1. the MOS Change Request Form (the MCR) bears an origination date, describes the change to be made and the desired operational date for the change, and also has the date when the MCR was approved (by a change control board at JPL);

2. the Parameter File is the text file to be actually used in the data processing and contains the Cal Table values for each cycle; and

3. the File Release Form contains the Parameter File creation date, the release approval date, and the date at which file execution is to begin.

The MCR Form is typically accompanied by other supporting information from WFF describing why the change is being requested.

In Table 3-2 we have summarized information from copies of the sigma0-related MCRs and File Release Forms relevant to the re-released GDRs and the MGDR-Bs. Columns 1 to 3 of Table 3-2 are transcribed from the MCR Forms, and columns 4 and 5 from the File Release Forms. Column 6 of Table 3-2 contains a brief indication of what change the MCR made and why, and column 7 indicates which of the TOPEX Side B GDRs were governed by each MCR.

3.2.3 Brief Review of Side A Sigma0 and of Sigma0 Corrections in Side B

In TOPEX Side A there were indications that the time trend of the CAL-1 AGC differed from the time trend of the over-ocean cycle-averaged sigma0 in both the Ku- and the C-band systems. We were forced to use the time trend of the over-ocean uncorrected sigma0 cycle-averages to produce the sigma0 Cal Table entries. We tried to make these corrections only for relatively long times, avoiding responding to cycle-to-cycle noise. Correcting a noisy process by making trend estimates projections is a frustrating activity at best, and the Side A Cal Table has several places where we failed to detect trend changes or to correct our trend projections soon enough. After TOPEX was switched to its Side B in early February 1999 we described the entire Side A Cal Table history in "TOPEX Sigma0 Calibration Table History for All Side A Data", G. S. Hayne and D. W. Hancock III, 27 July 1999, available at http://topex.wff.nasa.gov/docs/Sigma0CAL_A_All.pdf. In that paper we produced our best guess at what values the Cal Table should have included, based on a quadratic trend fit to the entire Side A set of over-ocean cycle-averages of uncorrected sigma0.

When Side B was turned on, initial Side B Cal Table entries were chosen in a committee process (involving P.S. Callahan and others) so that there was no obvious discontinuity in over-ocean sigma0 from Side A to Side B. These initial Cal Table values, indicated by the first entry (MCR 690) in Table 3-2, were held constant about a dozen cycles until trends became apparent.

Until almost cycle 300, it appeared that the Side B over-ocean sigma0 trends could be adequately corrected by using the CAL-1 AGC trends, and here is a summary of the sigma0 corrections based on CAL-1 AGC trends. The Side B C-band Cal Table values were changed beginning with cycle 248 to correct for an apparent downward trend in the C-band over-ocean sigma0. No corrections were made to the Side B Ku-band Cal Table until cycle 259 when it became clear that there was an upward trend in the Ku-band over-ocean sigma0. Both the Ku- and the C-band Cal Table values were produced by assuming a linear trend in the over-ocean sigma0. The Ku-band system was particularly surprising in showing an increase in over-ocean sigma0 estimates before correction. Eventually it became clear that the linear trends in the Cal Table were overcorrecting the data, and the Cal Table values were held constant until the data trends caught up with the correction; this Cal Table freeze was made at cycle 274 for Ku-band and at cycle 278 for C-band.

At the end of cycle 287 we reassessed the CAL-1 AGC trends, representing them by two discontinuous line segments because of a step-change in the Ku-band CAL-1 AGC which appeared following a safe hold in cycle 256. Although the C-band CAL-1 AGC did not have as evident a discontinuity, we used two discontinuous segments for C-band as well as for Ku-band so that both Ku- and C-band sigma0 corrections were made in the same way. From the two-segment fits, a new set of Cal Table values was produced, and the GDRs for cycles 277 - 284 were reprocessed and re-released. GDRs for cycles 285 through 299 were released only with the new Cal Table values. The second through the fifth entries in Table 3-2 (MCR numbers 692, 701, 703, and 78) summarize the four different CAL-1 AGC trend fits used to correct the sigma0 data.

By cycle 300, however, it appeared that the CAL-1 AGC trends were starting to deviate from the uncorrected sigma0 trends, and we decided to base the sigma0 corrections on the uncorrected sigma0 trends as in Side A sigma0. The functional form chosen for the trend was now three line segments, with the first segment fitted to the uncorrected sigma0 from cycles 236 through 255; the second and third segments were forced to be continuous in value but with a discontinuity in slope with the initial intercept, the two slopes and the slope discontinuity point being determined by a fit to the uncorrected sigma0 above cycle 256. The last four entries in Table 3-2 summarize the different sigma0 corrections based on the different three-segment fits to uncorrected sigma0.

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Table 3-2 Sigma0-Related MCRs and File Release Form Information

From MCR Form			From File Release Form		Additional Information	
(1) MCR #	(2) MCR Origination Date	(3) Comments on MCR Form	(4) File Creation Date	(5) Approval Date	(6) Comments on MCR Actions and Reasons	(7) Cycles Distributed , This MCR
690	99/05/26 1999-146	After indicated parameter & constant changes, produce IGDRs and GDRs from all Alt-B data to date	1999/05/25 1999-145	1999/05/28	After initial Cal/Val activity, set constant Ku and C biases with values chosen to make smooth connection to Side A results.	236 - 247
692	99/06/16 1999-167	See attachment request memo from P. Callahan	1999/06/17 1999-168	1999/06/17	C-band has a trend estimated from first 12 cycles (1st C-band change is at cycle 242), Ku-band has zero trend.	248 - 258
701	2000/01/10 2000-010	Begin use for cycle 259	2000/01/13 2000-013	2000/01/13	Put in linear trend for Ku, and changed linear trend for C. Still assuming single linear trends from cycle 236 for Ku and for C.	259 - 276
703	2000/04/03 2000-094	Begin use for cycle 279 onward	2000/04/04 2000-095	2000/04/04	The correction trends of MCR 701 were getting too large, and a temporary freeze was put in to hold values constant from 278 forward.	--
708	2000/07/18 2000-200	Begin use for cycle 288, reprocess 277-287; table change for cycle 236 forward, but cycles 236-276 won't be corrected at this time	2000/07/19 2000-201	2000/07/19	Side B trends (Ku particularly) show step-change at cycle 256; use two line segments (with step change at cycle 256) fitted to CAL-1 trends for producing Side B calibration table entries.	277 - 299
720	2000/12/06 2000-341	Begin use for cycle 303; reprocess sdr->IGDR for cycles 300-302	2000/12/07 2000-342	2000/12/07	Side B sigma0 trends have started to deviate from CAL-1 trends; now a three-segment line fit to sigma0 trends will be used for the Side B calibration table entries.	300 - 326
740	2001/09/17 2001-260	Begin use for cycle 327; reprocess IGDRs, GDRs for 327 forward	2001/09/17 2001-260	2001/09/17	The three-segment line fit (to sigma0 trends) was revised using data from approximately twenty cycles since the last trend fit, and a new set of Side B calibration table entries was produced.	327 - 350

Table 3-2 Sigma0-Related MCRs and File Release Form Information

From MCR Form			From File Release Form		Additional Information	
(1) MCR #	(2) MCR Origination Date	(3) Comments on MCR Form	(4) File Creation Date	(5) Approval Date	(6) Comments on MCR Actions and Reasons	(7) Cycles Distributed, This MCR
747	2002/03/18 2002-077	Begin use for cycle 351	2002/03/21 2002-080	2002/03/25	The three-line-segment trend fit was revised using data through cycle 345, and a new set of Side B calibration table entries was produced.	351 - 374
754	2002/12/04 2002-338	Begin use at cycle 375	2002/12/05 2002-339	2002/12/05	The trend established by MCR 747 was overcorrecting the sigma0, and the calibration table values were frozen at the table's cycle 374 entry.	375 - -

3.2.4 Latest Fitted Sigma0 Trends for Estimation of Cal Table Values

Figure 3-12 and Figure 3-13 on page 3-21 show quantities related to return power estimation for the Side B Ku- and C-Band altimeters. Some of these quantities have been shifted to use a common vertical plot axis. Although these figures are too busy, the divergence of the sigma0 trend from the CAL-1 AGC trend can be seen starting somewhere around cycle 300. This divergence is more pronounced in C-Band, but also apparently present in Ku-band. Because of the divergence of the Side B CAL-1 and sigma0 trends, we decided to use the sigma0 trend as the basis for the Side B sigma0 Cal Table values. For all sigma0 trend fits we have first applied to the uncorrected sigma0 a seasonal correction which is based on the Side A data from cycles 17 through 235.

Since cycle 300 we have been fitting straight line segments to the Side B sigma0 data with a discontinuity in slope and value of the fit at cycle 256 to allow for the possible step change in altimeter characteristics; the sigma0 data after cycle 256 was modeled by two straight line segments having continuous values but allowing a discontinuity in the slope. The cycle at which the slope changed was one of the variable fit parameters, so the fits consisted of three straight-line segments with the latter two connected to each other. By late year 2002 however the last of the line segments was beginning to show the need for a higher order fit than linear. A functional form was needed that allowed some curvature, so the last (rightmost) of the three linear segments was replaced by the rational polynomial form $y = (a_0 + a_1{*}x + a_2{*}x^2) / (1 + b_1{*}x)$, where a_0, a_1, a_2, and b_1 are fit coefficients and x is data cycle number. The a_0 is further constrained by the requirement that the second-to-third segment fit value be continuous. Figure 3-14 on page 3-22 shows the sigma0 and the fitted line segments for both Ku-

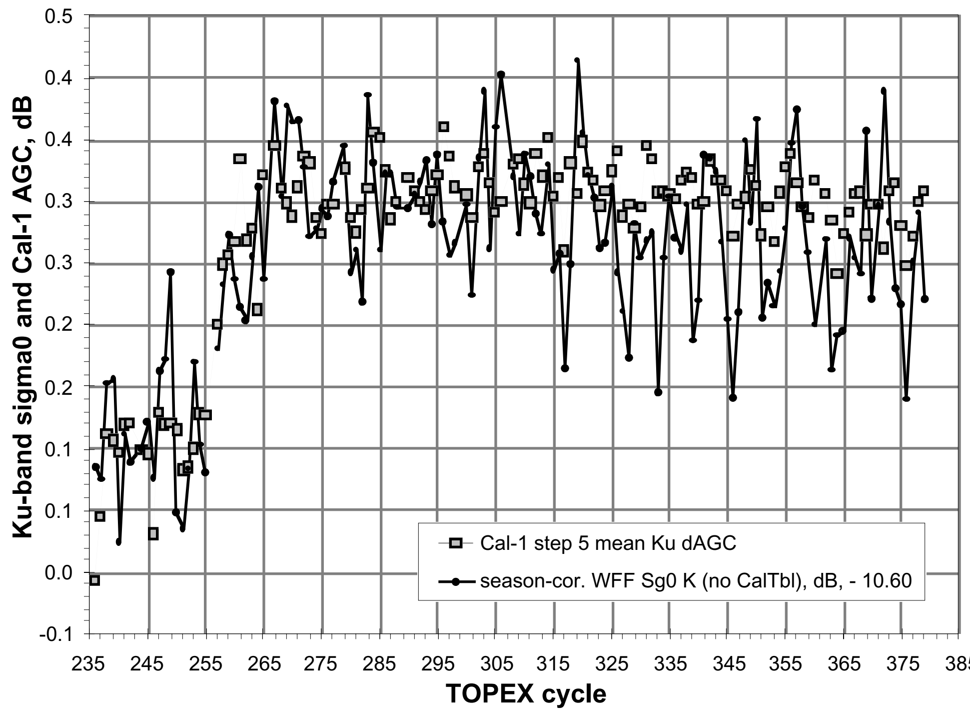

Figure 3-12 Ku-Band Cycle-Averaged CAL-1 Delta AGC and Season-Corrected Sigma0 (Cal Table Removed) vs. Data Cycle

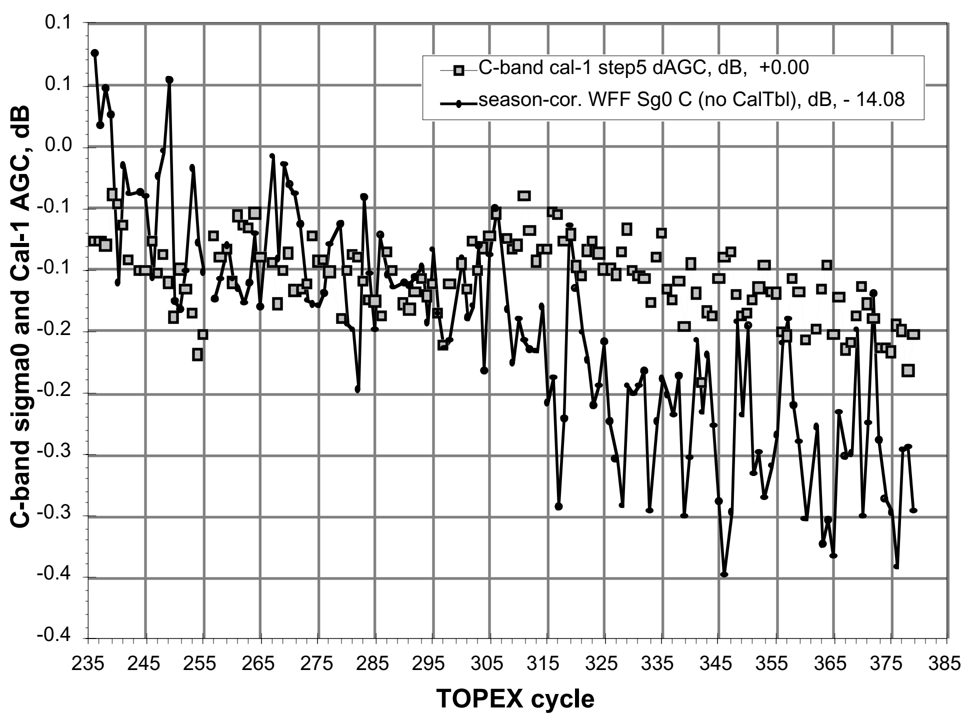

Figure 3-13 C-Band Cycle-Averaged CAL-1 Delta AGC and Season-Corrected Sigma0 (Cal Table Removed) vs. Data Cycle

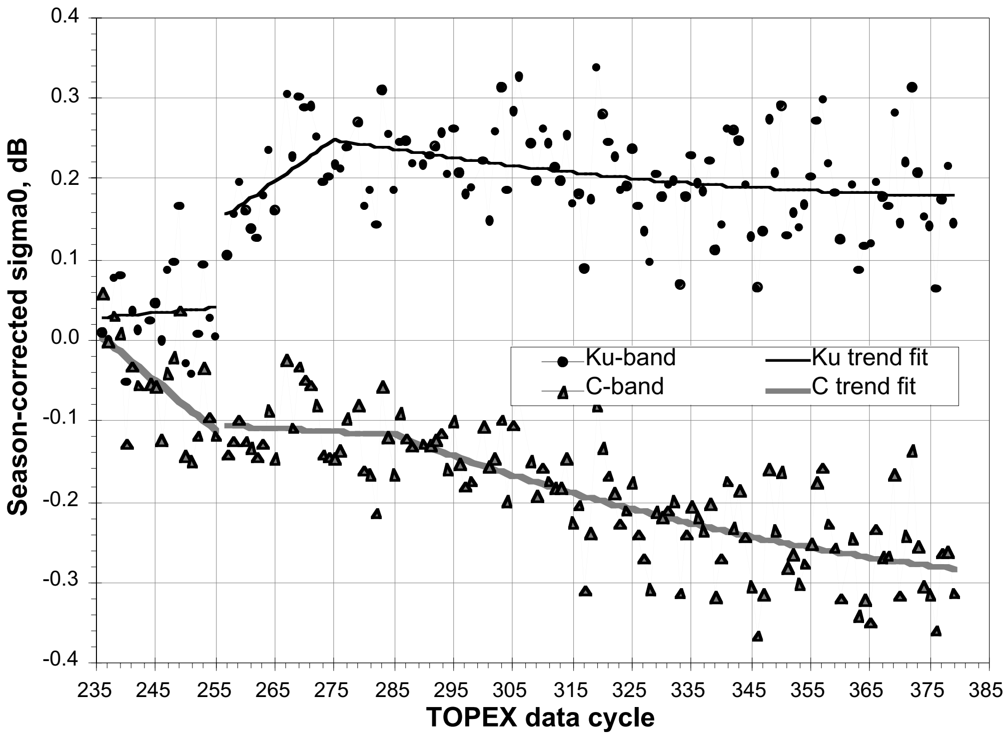

Figure 3-14 Side B Season-Corrected Sigma0 (Cal Table Removed) and Fitted Trends Relative to Cycle 237 *vs*. Data Cycle

and C-band for equally-weighted least-squares fitting to the three-segment form just described.

The (negatives of) the Figure 3-14 data provide relative sigma0 corrections, and it was arbitrarily decided to set the relative corrections to zero at cycle 240; that is, we assumed that +0.45 dB was the correct Ku-band Cal Table value and that +0.55 dB was the correct C-band Cal Table value at cycle 240. From the line-segment fits we calculated the values given in the fourth and fifth columns of Table 3-3.

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
236	+0.450	+0.550	0.452	0.526	+0.002	-0.024
237	+0.450	+0.550	0.452	0.532	+0.002	-0.018
238	+0.450	+0.550	0.451	0.538	+0.001	-0.012
239	+0.450	+0.550	0.451	0.544	+0.001	-0.006

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
240	+0.450	+0.550	0.450	0.550	+0.000	+0.000
241	+0.450	+0.550	0.449	0.556	-0.001	+0.006
242	+0.450	+0.550	0.449	0.562	-0.001	+0.012
244	+0.450	+0.550	0.448	0.574	-0.002	+0.024
245	+0.450	+0.550	0.447	0.581	-0.003	+0.031
246	+0.450	+0.550	0.446	0.587	-0.004	+0.037
247	+0.450	+0.550	0.446	0.593	-0.004	+0.043
248	+0.450	+0.610	0.445	0.599	-0.005	-0.011
249	+0.450	+0.610	0.445	0.605	-0.005	-0.005
250	+0.450	+0.610	0.444	0.611	-0.006	+0.001
251	+0.450	+0.610	0.443	0.617	-0.007	+0.007
252	+0.450	+0.610	0.443	0.623	-0.007	+0.013
253	+0.450	+0.640	0.442	0.630	-0.008	-0.010
254	+0.450	+0.640	0.442	0.636	-0.008	-0.004
255	+0.450	+0.640	0.441	0.642	-0.009	+0.002
257	+0.450	+0.640	0.326	0.635	-0.124	-0.005
258	+0.450	+0.640	0.321	0.636	-0.129	-0.004
259	+0.270	+0.640	0.315	0.636	+0.045	-0.004
260	+0.270	+0.640	0.310	0.636	+0.040	-0.004
261	+0.270	+0.640	0.305	0.637	+0.035	-0.003
262	+0.240	+0.640	0.300	0.637	+0.060	-0.003
263	+0.240	+0.670	0.295	0.638	+0.055	-0.032
264	+0.240	+0.670	0.290	0.638	+0.050	-0.032

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
265	+0.240	+0.670	0.284	0.638	+0.044	-0.032
267	+0.210	+0.670	0.274	0.639	+0.064	-0.031
268	+0.210	+0.670	0.269	0.640	+0.059	-0.030
269	+0.210	+0.670	0.264	0.640	+0.054	-0.030
270	+0.180	+0.700	0.259	0.640	+0.079	-0.060
271	+0.180	+0.700	0.254	0.641	+0.074	-0.059
272	+0.180	+0.700	0.248	0.641	+0.068	-0.059
273	+0.180	+0.700	0.243	0.642	+0.063	-0.058
274	+0.150	+0.700	0.238	0.642	+0.088	-0.058
275	+0.150	+0.700	0.233	0.642	+0.083	-0.058
276	+0.150	+0.700	0.234	0.643	+0.084	-0.057
277	+0.210	+0.580	0.235	0.643	+0.025	+0.063
279	+0.210	+0.580	0.238	0.644	+0.028	+0.064
280	+0.210	+0.580	0.239	0.644	+0.029	+0.064
281	+0.210	+0.580	0.240	0.645	+0.030	+0.065
282	+0.210	+0.580	0.241	0.645	+0.031	+0.065
283	+0.210	+0.610	0.242	0.646	+0.032	+0.036
284	+0.210	+0.610	0.243	0.646	+0.033	+0.036
285	+0.210	+0.610	0.245	0.647	+0.035	+0.037
286	+0.210	+0.610	0.246	0.649	+0.036	+0.039
287	+0.210	+0.610	0.247	0.652	+0.037	+0.042
288	+0.210	+0.610	0.248	0.655	+0.038	+0.045
290	+0.180	+0.610	0.250	0.660	+0.070	+0.050
291	+0.180	+0.610	0.251	0.662	+0.071	+0.052

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
292	+0.180	+0.610	0.252	0.665	+0.072	+0.055
293	+0.180	+0.610	0.253	0.668	+0.073	+0.058
294	+0.180	+0.610	0.254	0.670	+0.074	+0.060
295	+0.180	+0.610	0.255	0.673	+0.075	+0.063
296	+0.180	+0.610	0.256	0.675	+0.076	+0.065
297	+0.180	+0.610	0.257	0.678	+0.077	+0.068
298	+0.180	+0.610	0.258	0.680	+0.078	+0.070
300	+0.240	+0.610	0.260	0.685	+0.020	+0.075
301	+0.240	+0.610	0.261	0.687	+0.021	+0.077
302	+0.240	+0.610	0.262	0.690	+0.022	+0.080
303	+0.240	+0.610	0.263	0.692	+0.023	+0.082
304	+0.240	+0.610	0.264	0.694	+0.024	+0.084
305	+0.240	+0.640	0.265	0.697	+0.025	+0.057
306	+0.240	+0.640	0.266	0.699	+0.026	+0.059
308	+0.240	+0.640	0.267	0.703	+0.027	+0.063
309	+0.240	+0.640	0.268	0.706	+0.028	+0.066
310	+0.240	+0.640	0.269	0.708	+0.029	+0.068
311	+0.240	+0.640	0.270	0.710	+0.030	+0.070
312	+0.240	+0.640	0.271	0.712	+0.031	+0.072
313	+0.240	+0.640	0.272	0.714	+0.032	+0.074
314	+0.240	+0.640	0.272	0.717	+0.032	+0.077
315	+0.240	+0.640	0.273	0.719	+0.033	+0.079
316	+0.240	+0.640	0.274	0.721	+0.034	+0.081
317	+0.240	+0.640	0.275	0.723	+0.035	+0.083

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
318	+0.240	+0.640	0.276	0.725	+0.036	+0.085
319	+0.240	+0.640	0.276	0.727	+0.036	+0.087
320	+0.240	+0.640	0.277	0.729	+0.037	+0.089
321	+0.240	+0.640	0.278	0.731	+0.038	+0.091
322	+0.240	+0.640	0.278	0.733	+0.038	+0.093
323	+0.240	+0.640	0.279	0.735	+0.039	+0.095
324	+0.240	+0.640	0.280	0.737	+0.040	+0.097
325	+0.240	+0.640	0.281	0.739	+0.041	+0.099
326	+0.240	+0.640	0.281	0.741	+0.041	+0.101
327	+0.270	+0.760	0.282	0.742	+0.012	-0.018
328	+0.270	+0.760	0.283	0.744	+0.013	-0.016
329	+0.270	+0.760	0.283	0.746	+0.013	-0.014
330	+0.270	+0.760	0.284	0.748	+0.014	-0.012
331	+0.270	+0.760	0.284	0.750	+0.014	-0.010
332	+0.270	+0.760	0.285	0.752	+0.015	-0.008
333	+0.270	+0.760	0.286	0.753	+0.016	-0.007
334	+0.270	+0.760	0.286	0.755	+0.016	-0.005
335	+0.270	+0.760	0.287	0.757	+0.017	-0.003
336	+0.270	+0.760	0.287	0.758	+0.017	-0.002
337	+0.300	+0.760	0.288	0.760	-0.012	+0.000
338	+0.300	+0.790	0.289	0.762	-0.011	-0.028
339	+0.300	+0.790	0.289	0.763	-0.011	-0.027
340	+0.300	+0.790	0.290	0.765	-0.010	-0.025
341	+0.300	+0.790	0.290	0.767	-0.010	-0.023

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
342	+0.300	+0.790	0.291	0.768	-0.009	-0.022
343	+0.300	+0.790	0.291	0.770	-0.009	-0.020
344	+0.300	+0.790	0.292	0.771	-0.008	-0.019
345	+0.300	+0.790	0.292	0.773	-0.008	-0.017
346	+0.300	+0.790	0.293	0.774	-0.007	-0.016
347	+0.300	+0.790	0.293	0.776	-0.007	-0.014
348	+0.300	+0.790	0.293	0.777	-0.007	-0.013
349	+0.300	+0.790	0.294	0.779	-0.006	-0.011
350	+0.300	+0.790	0.294	0.780	-0.006	-0.010
351	+0.300	+0.820	0.295	0.781	-0.005	-0.039
352	+0.300	+0.820	0.295	0.783	-0.005	-0.037
353	+0.300	+0.820	0.295	0.784	-0.005	-0.036
354	+0.300	+0.820	0.296	0.785	-0.004	-0.035
355	+0.300	+0.820	0.296	0.787	-0.004	-0.033
356	+0.300	+0.820	0.296	0.788	-0.004	-0.032
357	+0.300	+0.820	0.297	0.789	-0.003	-0.031
358	+0.330	+0.820	0.297	0.790	-0.033	-0.030
359	+0.330	+0.820	0.297	0.792	-0.033	-0.028
360	+0.330	+0.820	0.298	0.793	-0.032	-0.027
362	+0.330	+0.820	0.298	0.795	-0.032	-0.025
363	+0.330	+0.850	0.299	0.796	-0.031	-0.054
364	+0.330	+0.850	0.299	0.798	-0.031	-0.052
365	+0.330	+0.850	0.299	0.799	-0.031	-0.051
366	+0.330	+0.850	0.299	0.800	-0.031	-0.050

Table 3-3 TOPEX Side B Sigma0 Cal Table Values

	CalTable values Used in Already-Distributed GDRs		New Cal Table Values from Trend Fit		"Delta" CalTable Values, to Add to Already-Distributed GDR Sigma0	
Data Cycle	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB	Ku-Band, dB	C-Band, dB
367	+0.330	+0.850	0.299	0.801	-0.031	-0.049
368	+0.330	+0.850	0.300	0.802	-0.030	-0.048
369	+0.330	+0.850	0.300	0.803	-0.030	-0.047
370	+0.330	+0.850	0.300	0.804	-0.030	-0.046
371	+0.330	+0.850	0.300	0.805	-0.030	-0.045
372	+0.330	+0.850	0.300	0.806	-0.030	-0.044
373	+0.330	+0.850	0.301	0.807	-0.029	-0.043
374	+0.330	+0.850	0.301	0.808	-0.029	-0.042
375	+0.330	+0.850	0.301	0.809	-0.029	-0.041
376	+0.330	+0.850	0.301	0.809	-0.029	-0.041
377	+0.330	+0.850	0.301	0.810	-0.029	-0.040
378	+0.330	+0.850	0.301	0.811	-0.029	-0.039

These are our best current guess at the values which should have been in the Cal Table, and if one were to calculate GDRs one should use these (fourth and fifth column) numbers as replacements for the values used in the original GDR production (given in the second and third columns of Table 3-3).

The sixth and seventh columns in Table 3-3 give the (additive) amounts by which the already-distributed Ku- and C-band sigma0 values can be adjusted for the new fitted Cal Table values. The old Cal Table values and the fitted new Cal Table values are plotted for Ku-band in Figure 3-15 on page 3-29 and for C-band in Figure 3-16 on page 3-29. Figure 3-17 on page 3-30 shows that the Ku-band sigma0 values for cycles 257 and 258 are the most in need of additional adjustment, because no change in the Ku Cal Table had been made from start of Side B until cycle 259.

We continually monitor the altimeter's power-related trends, and we document these trends at the web site http://topex.wff.nasa.gov/docs/docs.html.

3.3 Side B Point Target Response

Changes in the TOPEX Side A altimeter became apparent around the middle of 1998. The first symptoms of the changes were an increase in the altimeter's SWH estimates

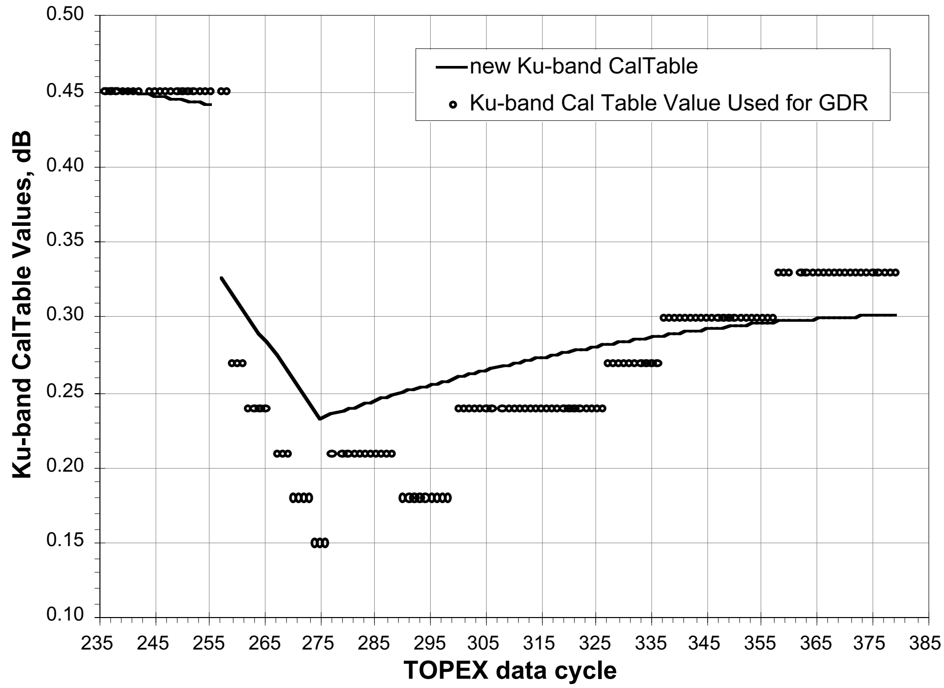

Figure 3-15 Side B Ku-band Old and New Cal Table Values *vs*. Data Cycle

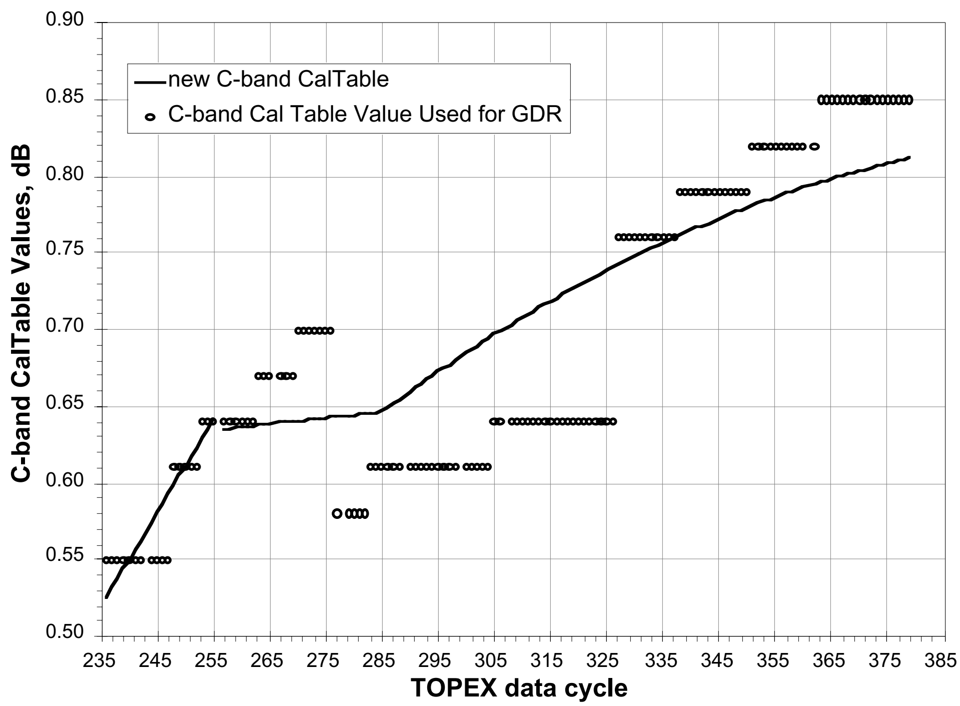

Figure 3-16 Side B C-band Old and New Cal Table Values *vs*. Data Cycle

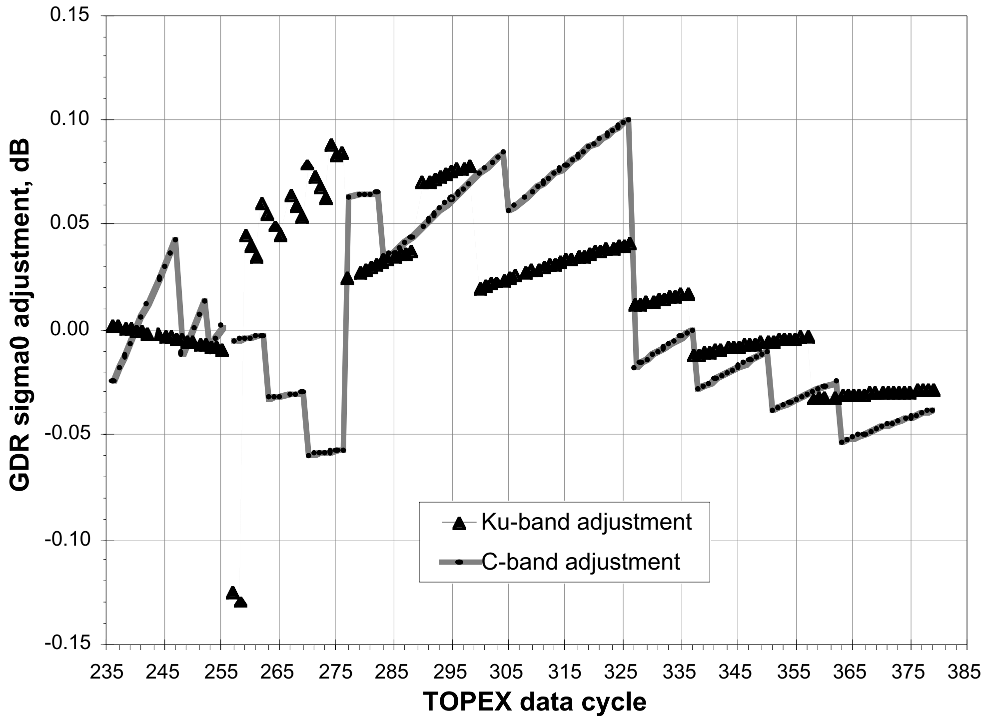

Figure 3-17 Side B Sigma0 Adjustments *vs*. Data Cycle (values to add to GDR sigma0, to replace "old" by "new" Cal Table)

and an increase in the range rms. Subsequent investigation revealed apparent changes in the altimeter's point target response (PTR); these changes were shown by the waveform data in the altimeter's calibration Mode 1 (CAL-1). The Side A PTR changes were the reason that the altimeter was switched to its Side B in February 1999 near the start of cycle 236.

The normal TOPEX CAL-1 has been executed at least twice daily throughout the entire TOPEX operation. In CAL-1 a portion of the transmitted signal is fed back into the altimeter receiver through a special calibration attenuator and the altimeter tracks this transmitted signal using a special tracking algorithm. During the preflight testing a special calibration mode sweep test (the CalSweep) had been developed in which the altimeter did not automatically track the PTR; instead the AGC level was frozen at a preset level and the altimeter's fine-height word was incremented through its entire range (equivalent to 8 waveform sample positions). The CalSweep waveforms can be processed to give a "fine-grained" look at the PTR. After the Side A overestimates of SWH became apparent, a software patch was uploaded to TOPEX to allow the CalSweep to be executed on-orbit. The CalSweep was executed approximately monthly from mid-1998 through the end of the Side A operation. The year 1998 Engineering Assessment Update (published in August 1999) contains a more detailed discussion of the Side A PTR observation by CAL-1 and CalSweep, and the consequences of the Side A PTR change.

The CalSweep continued to be executed once every three data cycles (about once a month) for the entire time of Side B operation until the CAL-1 delta range meandering appeared early in cycle 364. From that time onward, the CalSweep has been executed once per data cycle. The increase in number of CalSweeps was an attempt to find other TOPEX changes which could be correlated with the onset of the CAL-1 delta range meandering. Although we have found nothing in the CalSweep results that can be associated with the change in the CAL-1 delta ranges, the CalSweeps continue to be executed once per cycle.

Figure 3-18 shows the comparison of an early Side B CalSweep (1999 day 042) and

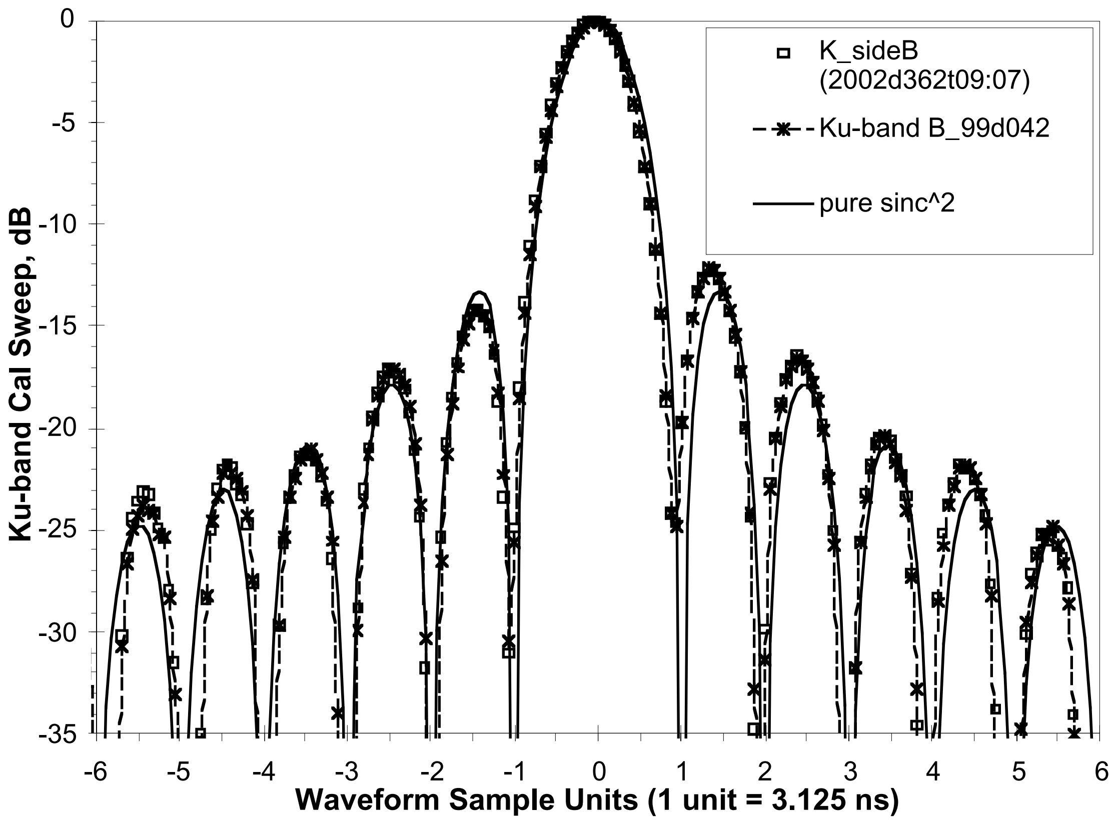

Figure 3-18 TOPEX Ku-Band CalSweep 2002 Day 362

the last Ku-band CalSweep of year 2002 (2002 day 362). Figure 3-19 on page 3-32 shows the same comparison for the Side B C-band altimeter. As a reference, the theoretical model for the PTR is shown by the pure sinc^2 function plotted in Figure 3-18 and Figure 3-19. Only the central lobe and the first five sidelobes are shown in these figures. To within the accuracy and repeatability of the CalSweep, there has been little perceptible change in the Side B Ku- and C-band CalSweeps from start of Side B through the end of year 2002. These changes have only been of the order of the size of the plot symbols, with slightly more visible change in C-Band than in Ku-band.

In addition to the CalSweep, further information on the PTR is available from the waveform data in the normal CAL-1 which is executed about twenty times in each

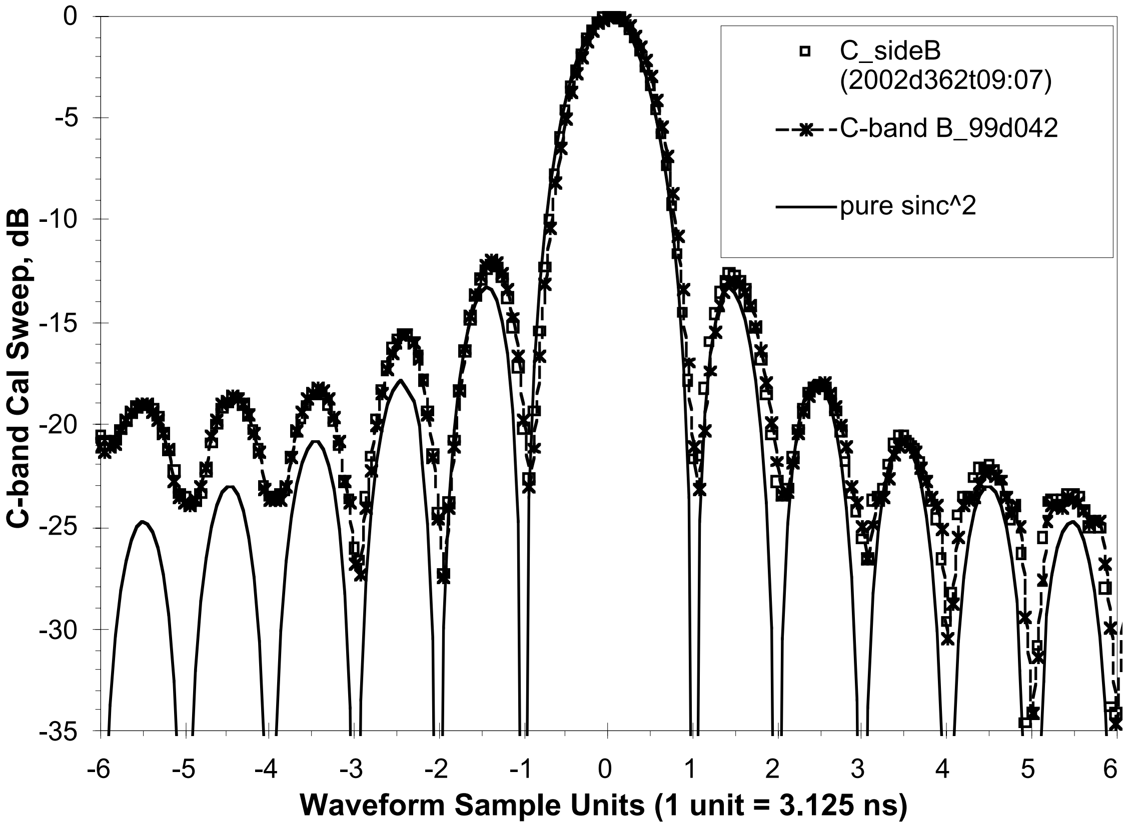

Figure 3-19 TOPEX C-Band CalSweep 2002 Day 362

TOPEX repeat cycle. While the CalSweep "paints" the PTR in fine-grained detail, the CAL-1 waveform only provides a single sample at about the peak of each of the PTR sidelobes. We keep a database of waveforms from the first two CAL-1 modes in each repeat cycle, and this provides another way of assessing possible PTR changes as a function of cycle. We will use the CAL-1 step 5 waveforms for the following discussion because the AGC level of step 5 is about the same level as in the TOPEX normal over-ocean fine track.

For the TOPEX Side B Ku-band system, Figure 3-20 on page 3-33 shows the time history of the first five PTR lobes below the main peak and Figure 3-21 on page 3-33 shows the first five lobes above the main peak. These two figures show the Ku-band data from start of Side B operation through the end of cycle 379 (the last cycle starting in year 2002), and none of the sidelobe peak values exhibit any significant time trend. For the Side B C-band system, Figure 3-22 on page 3-34 shows the first five PTR lobes below the main peak and Figure 3-23 on page 3-34 shows the first five sidelobes above the main peak. While the lower five C-band Side B PTR sidelobes in Figure 3-22 show no significant time trends, there are possible small trends in a couple of the upper five C-band sidelobes in Figure 3-23. The +2 sidelobe shows an increase of about a half dB from start of Side B through the end of cycle 379, and the +3 sidelobe shows about an increase for about 3/4 dB over this time. Figure 3-23 may possibly show a step change in these sidelobes at the cycle 256 safehold about 208 days after

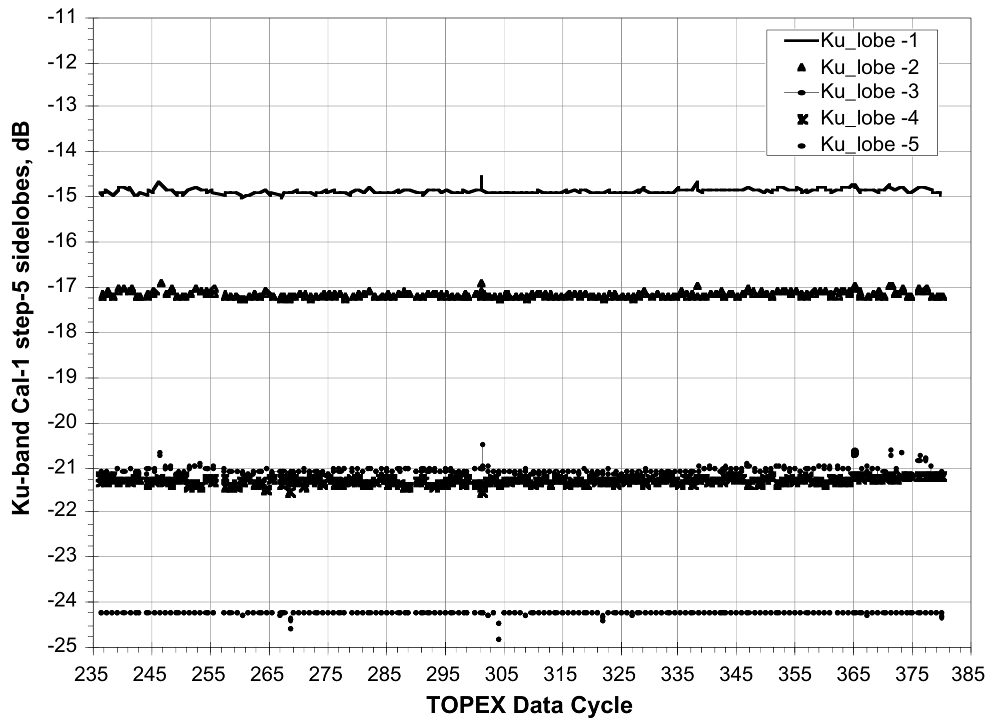

Figure 3-20 Side B Ku-band CAL-1 Lower Sidelobes Relative to Peak Value *vs*. Data Cycle

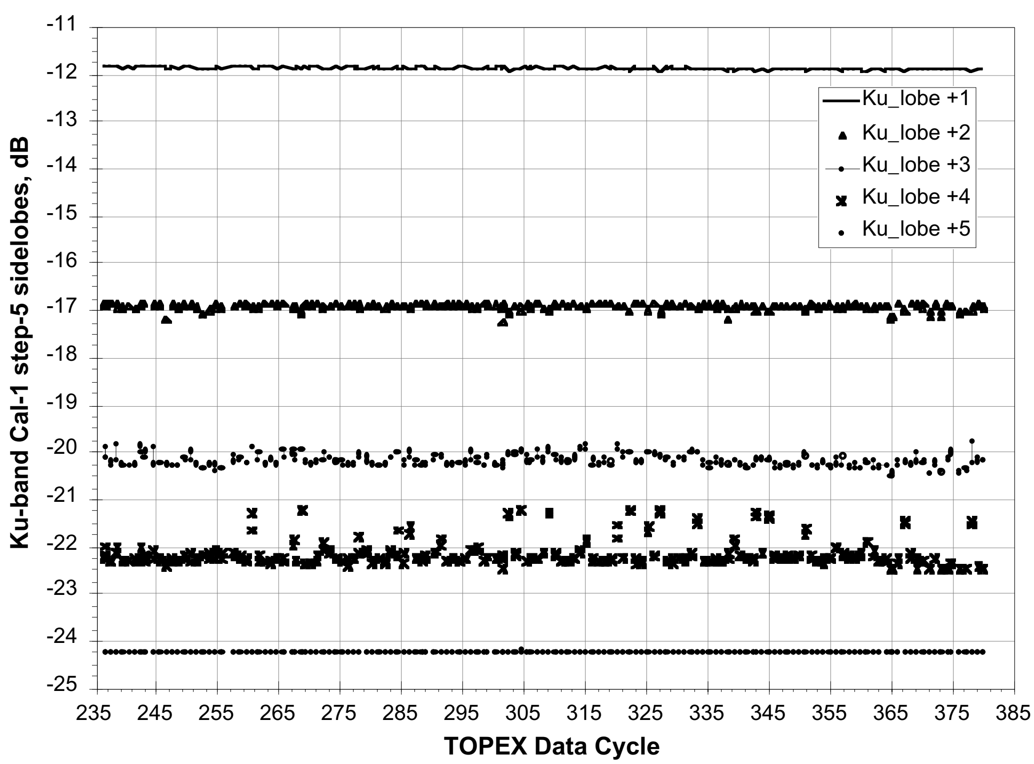

Figure 3-21 Side B Ku-band CAL-1 Higher Sidelobes Relative to Peak Value *vs*. Data Cycle

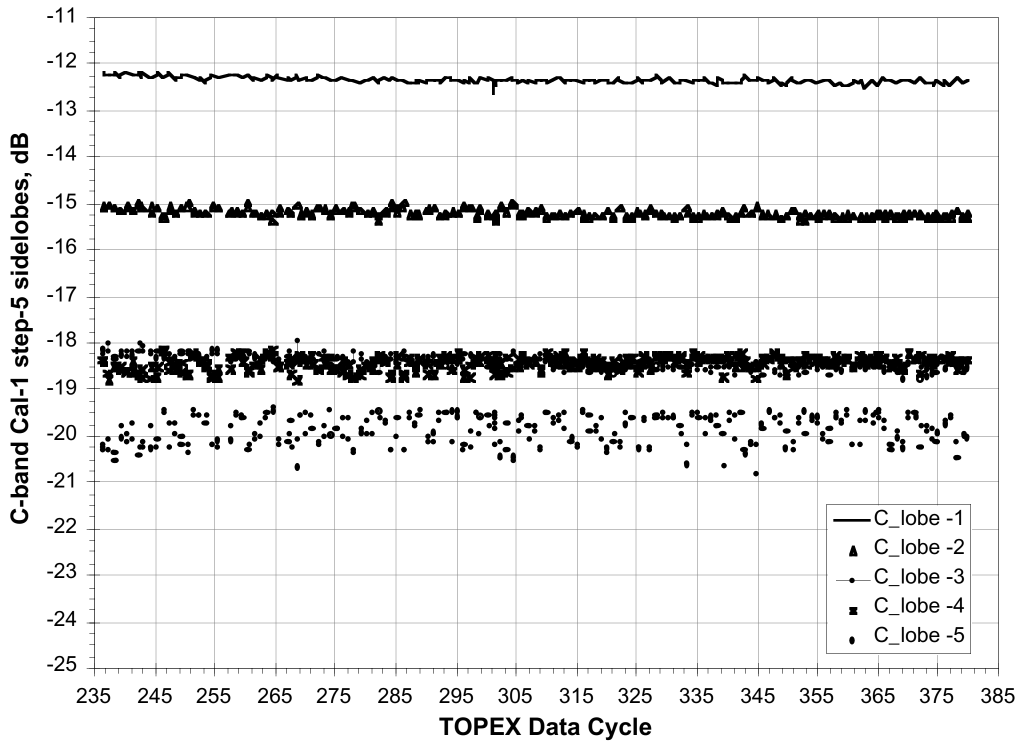

Figure 3-22 Side B C-band CAL-1 Lower Sidelobes Relative to Peak Value *vs*. Data Cycle

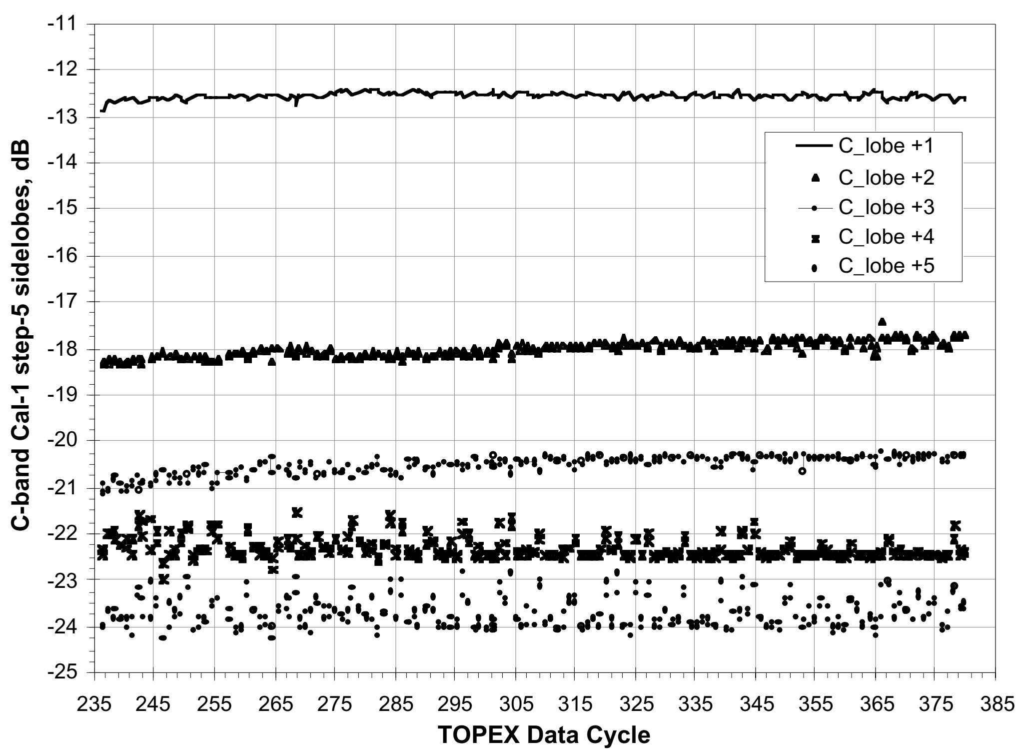

Figure 3-23 Side B C-band CAL-1 Higher Sidelobes Relative to Peak Value *vs*. Data Cycle

the start of Side B operation. We think that these changes are too small to have any practical consequences in the TOPEX range or SWH estimation, but future CalSweep and CAL-1 waveform trend results will be closely watched for possible further changes.

Section 4

Ancillary Performance Assessments

4.1 Range Measurement Noise

The TOPEX altimeter white noise levels have been evaluated using a technique, based on high-pass filtering of 1-Hz sea surface height time series, as described in Section 4.2 of the "TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001, June 2001. This filtering technique isolates the portion of the spectrum that should be dominated by the white noise floor and interpreted as the contribution of the instrument noise. It is simpler to use than repeat track-sampling comparisons, allows the analysis of much larger amounts of data, and in this manner, is more efficient in estimating the noise. This monitoring of the noise level of the altimeter over time should help to detect hardware changes.

The noise level estimates provided in Table 4-1 show stable characteristics from cycle-to-cycle with the basic linear dependence of the noise level upon significant wave-height (SWH). The TOPEX altimeter noise level is estimated to be about 1.8 cm for a 2 m SWH, as shown in Figure 4-1, when solving the fitted equation.

Note: Cycles 243, 256, 266, 278, 289, 299, 307, and 361 are omitted because they occurred during CNES SSALT operations.

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
236	2.846	1.219	2.204	0.803	1.806
237	2.840	1.314	2.168	0.798	1.784
238	2.763	1.129	2.152	0.735	1.807
239	2.789	1.235	2.151	0.769	1.789
240	3.054	1.342	2.327	0.887	1.815
241	2.951	1.203	2.220	0.755	1.803
242	2.861	1.249	2.163	0.743	1.789
244	2.895	1.430	2.195	0.830	1.800
245	2.863	1.435	2.203	0.859	1.806
246	2.891	1.390	2.221	0.829	1.814
247	2.949	1.417	2.268	0.870	1.833
248	2.873	1.429	2.204	0.842	1.813

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
249	2.679	1.261	2.108	0.745	1.820
250	2.984	1.574	2.248	0.885	1.808
251	3.049	1.493	2.284	0.887	1.800
252	2.931	1.478	2.233	0.870	1.814
253	2.784	1.334	2.153	0.772	1.811
254	2.843	1.486	2.185	0.869	1.795
255	2.940	1.494	2.223	0.866	1.796
257	2.845	1.381	2.177	0.797	1.804
258	3.031	1.449	2.272	0.849	1.806
259	2.786	1.407	2.161	0.849	1.794
260	2.931	1.460	2.261	0.888	1.818
261	2.913	1.387	2.207	0.833	1.788
262	2.811	1.294	2.157	0.776	1.796
263	2.808	1.258	2.162	0.745	1.809
264	2.719	1.204	2.127	0.737	1.808
265	2.677	1.191	2.087	0.721	1.791
267	2.651	1.238	2.104	0.792	1.786
268	2.707	1.270	2.136	0.799	1.800
269	2.599	1.227	2.069	0.761	1.790
270	2.634	1.141	2.065	0.664	1.809
271	2.692	1.198	2.129	0.756	1.804
272	2.761	1.251	2.139	0.752	1.807
273	2.903	1.295	2.230	0.847	1.786
274	2.961	1.323	2.241	0.798	1.812
275	2.955	1.314	2.231	0.805	1.791
276	2.935	1.327	2.243	0.833	1.805

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
277	2.968	1.274	2.247	0.830	1.796
279	2.834	1.293	2.166	0.778	1.793
280	2.898	1.313	2.196	0.790	1.803
281	2.907	1.438	2.221	0.871	1.795
282	3.055	1.565	2.336	0.936	1.836
283	2.723	1.335	2.117	0.784	1.798
284	2.832	1.291	2.185	0.811	1.799
285	2.824	1.360	2.149	0.801	1.784
286	2.879	1.450	2.206	0.845	1.805
287	2.793	1.356	2.152	0.794	1.806
288	2.918	1.460	2.231	0.865	1.811
290	2.892	1.436	2.192	0.824	1.799
291	2.890	1.456	2.208	0.872	1.791
292	2.883	1.384	2.195	0.816	1.796
293	2.756	1.403	2.155	0.817	1.810
294	2.811	1.422	2.174	0.833	1.800
295	2.861	1.378	2.175	0.806	1.790
296	2.932	1.355	2.211	0.785	1.815
297	2.816	1.287	2.145	0.746	1.801
298	2.793	1.269	2.152	0.779	1.803
300	2.616	1.193	2.098	0.745	1.814
301	2.799	1.240	2.161	0.779	1.788
302	2.737	1.139	2.117	0.712	1.794
303	2.676	1.233	2.109	0.770	1.793
304	2.895	1.313	2.202	0.810	1.787
305	2.765	1.179	2.138	0.746	1.789

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
306	2.686	1.204	2.119	0.761	1.801
308	2.756	1.130	2.123	0.716	1.784
309	2.785	1.178	2.140	0.725	1.792
310	2.726	1.131	2.114	0.699	1.798
311	2.802	1.273	2.187	0.781	1.820
312	2.931	1.316	2.245	0.840	1.806
313	2.897	1.322	2.188	0.799	1.795
314	2.872	1.291	2.186	0.775	1.810
315	2.975	1.302	2.216	0.789	1.781
316	2.906	1.331	2.206	0.810	1.803
317	2.890	1.287	2.191	0.780	1.790
318	2.947	1.466	2.253	0.894	1.803
319	2.774	1.327	2.182	0.814	1.832
320	2.720	1.309	2.124	0.773	1.806
321	2.738	1.335	2.133	0.773	1.809
322	2.781	1.274	2.135	0.743	1.801
323	2.934	1.523	2.223	0.873	1.803
324	2.973	1.432	2.237	0.840	1.801
325	2.904	1.508	2.235	0.903	1.808
326	2.875	1.437	2.190	0.841	1.795
327	3.053	1.473	2.274	0.870	1.794
328	2.853	1.426	2.172	0.824	1.790
329	2.820	1.324	2.166	0.766	1.808
330	2.866	1.507	2.207	0.894	1.796
331	3.156	1.450	2.321	0.858	1.790
332	2.942	1.353	2.206	0.788	1.803

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	**Mean**	**STD**	**Mean**	**STD**	**at 2m SWH**
333	2.980	1.362	2.237	0.825	1.780
334	2.835	1.257	2.197	0.773	1.812
335	2.643	1.156	2.084	0.711	1.796
336	2.758	1.182	2.134	0.724	1.803
337	2.861	1.189	2.174	0.770	1.771
338	2.607	1.065	2.048	0.655	1.787
339	2.728	1.116	2.096	0.670	1.790
340	2.724	1.080	2.106	0.654	1.807
341	2.637	1.071	2.066	0.671	1.795
342	2.707	1.151	2.147	0.733	1.827
343	**2.876**	**1.362**	**2.217**	**0.886**	**1.776**
344	**2.701**	**1.126**	**2.101**	**0.697**	**1.791**
345	**2.802**	**1.158**	**2.14**	**0.749**	**1.777**
346	**2.857**	**1.152**	**2.155**	**0.689**	**1.789**
347	**2.749**	**1.105**	**2.122**	**0.676**	**1.811**
348	**2.648**	**1.073**	**2.056**	**0.626**	**1.803**
349	**2.75**	**1.137**	**2.115**	**0.714**	**1.785**
350	**2.915**	**1.122**	**2.213**	**0.738**	**1.79**
351	**2.951**	**1.189**	**2.19**	**0.712**	**1.783**
352	**2.873**	**1.247**	**2.174**	**0.749**	**1.791**
353	**2.925**	**1.262**	**2.221**	**0.79**	**1.791**
354	**2.921**	**1.334**	**2.214**	**0.826**	**1.781**
355	**2.89**	**1.263**	**2.204**	**0.797**	**1.791**
356	**2.854**	**1.3**	**2.187**	**0.803**	**1.788**
357	**3.031**	**1.374**	**2.27**	**0.818**	**1.811**
358	**2.875**	**1.28**	**2.172**	**0.766**	**1.788**

Table 4-1 Statistical Indicators Based on 1-Minute Track Segments (Continued)

Time Period	SWH (m)		Noise Level (cm)		
Cycle	Mean	STD	Mean	STD	at 2m SWH
359	**2.973**	**1.357**	**2.231**	**0.852**	**1.763**
360	**3.073**	**1.389**	**2.283**	**0.842**	**1.781**
362	**2.983**	**1.523**	**2.229**	**0.857**	**1.792**
363	**3.221**	**1.446**	**2.321**	**0.821**	**1.801**
364	**3.098**	**1.45**	**2.268**	**0.839**	**1.777**
365	**3.073**	**1.422**	**2.273**	**0.871**	**1.764**
366	**2.9**	**1.308**	**2.149**	**0.764**	**1.761**
367	**2.92**	**1.393**	**2.227**	**0.844**	**1.793**
368	**2.879**	**1.42**	**2.177**	**0.814**	**1.786**
369	**2.891**	**1.246**	**2.184**	**0.755**	**1.787**
370	**2.83**	**1.222**	**2.158**	**0.731**	**1.796**
371	**2.944**	**1.289**	**2.23**	**0.801**	**1.79**
372	**2.818**	**1.249**	**2.175**	**0.759**	**1.809**
373	**2.668**	**1.166**	**2.089**	**0.683**	**1.811**
374	**2.869**	**1.172**	**2.178**	**0.733**	**1.785**
375	**2.74**	**1.104**	**2.112**	**0.722**	**1.767**
376	**2.968**	**1.26**	**2.227**	**0.795**	**1.769**
377	**2.802**	**1.056**	**2.129**	**0.686**	**1.771**
378	**2.702**	**1.022**	**2.11**	**0.663**	**1.793**

Note: The statistical indicators since last update are indicated by **bold** type.

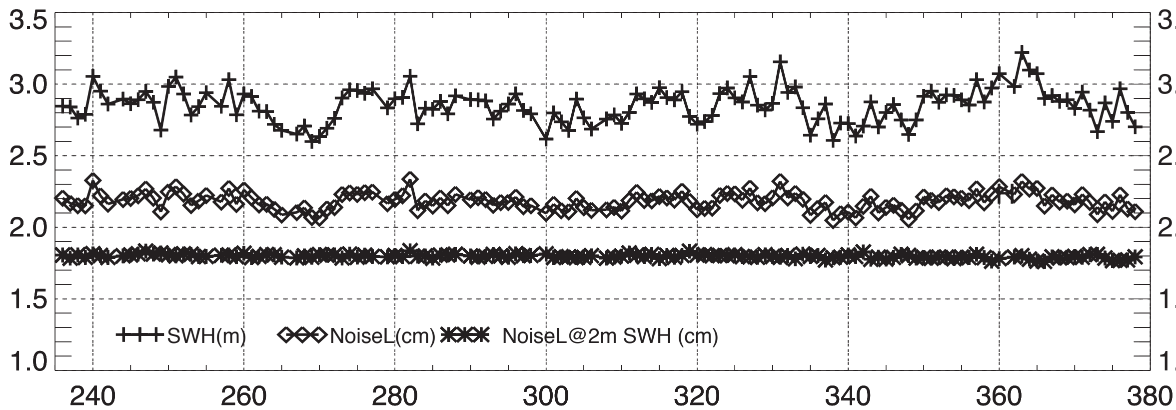

Figure 4-1 Plot of Selected Statistical Indicators from Table 4-1

4.2 Differencing as a Continuing System Health Monitor

An ancillary method of performance analysis we use is the differencing of parameters. The method has proven to be effective in verifying system stability.

Figure 4-2 "Cycle-Average SWH Delta in Meters" plots cycle averages of the C-band minus Ku-band significant waveheight difference, from the initial turn-on of Side B to the end of year 2002. The entire range of the delta SWHs is very small, only about 0.01 meters, and we expect to use the delta SWH cycle-averages as a continuing system health monitor rather than as a product having any particular science usefulness.

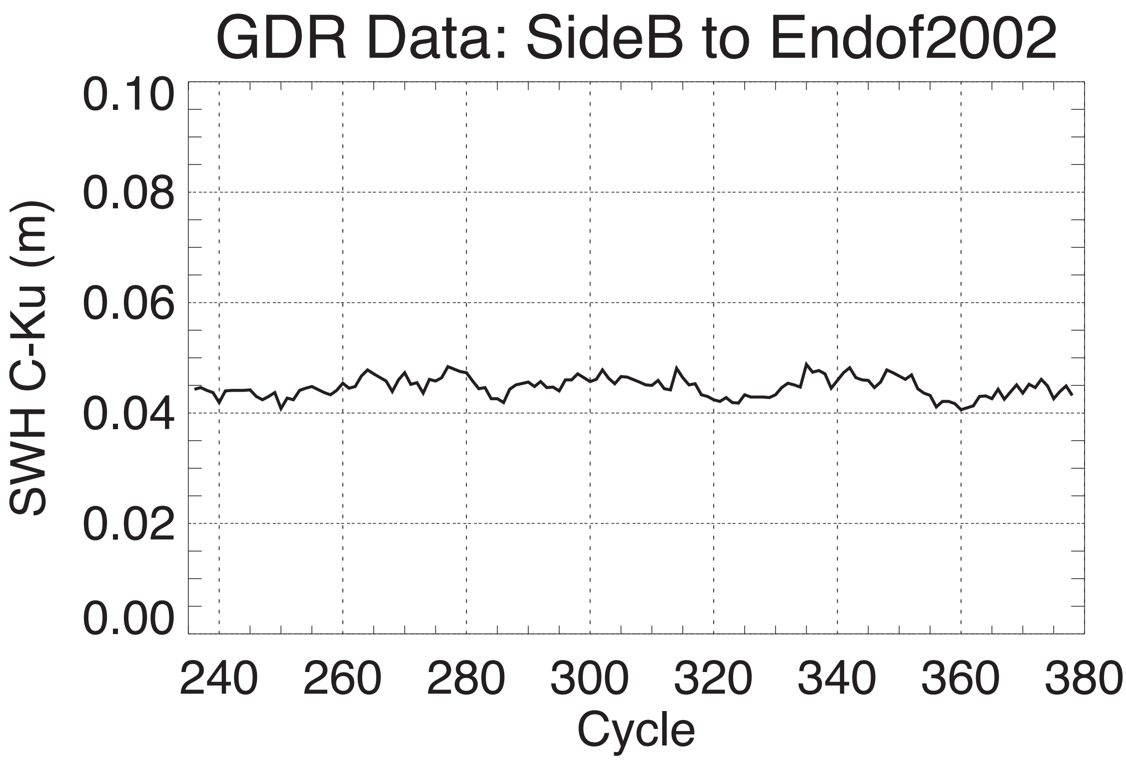

Figure 4-2 Cycle-Average SWH Delta in Meters

Figure 4-3 "Cycle-Average Gate Index Delta" plots cycle averages of the gate index delta, the difference between the secondary (C-band) and the primary (Ku-band) gate index, from Side B turn-on to the end of year 2002. The secondary gate is designated in the plot as SC, and the primary gate is PR. We see a small and sufficiently steady difference between the gate selection for each of the two frequencies. This figure is again a system health monitor.

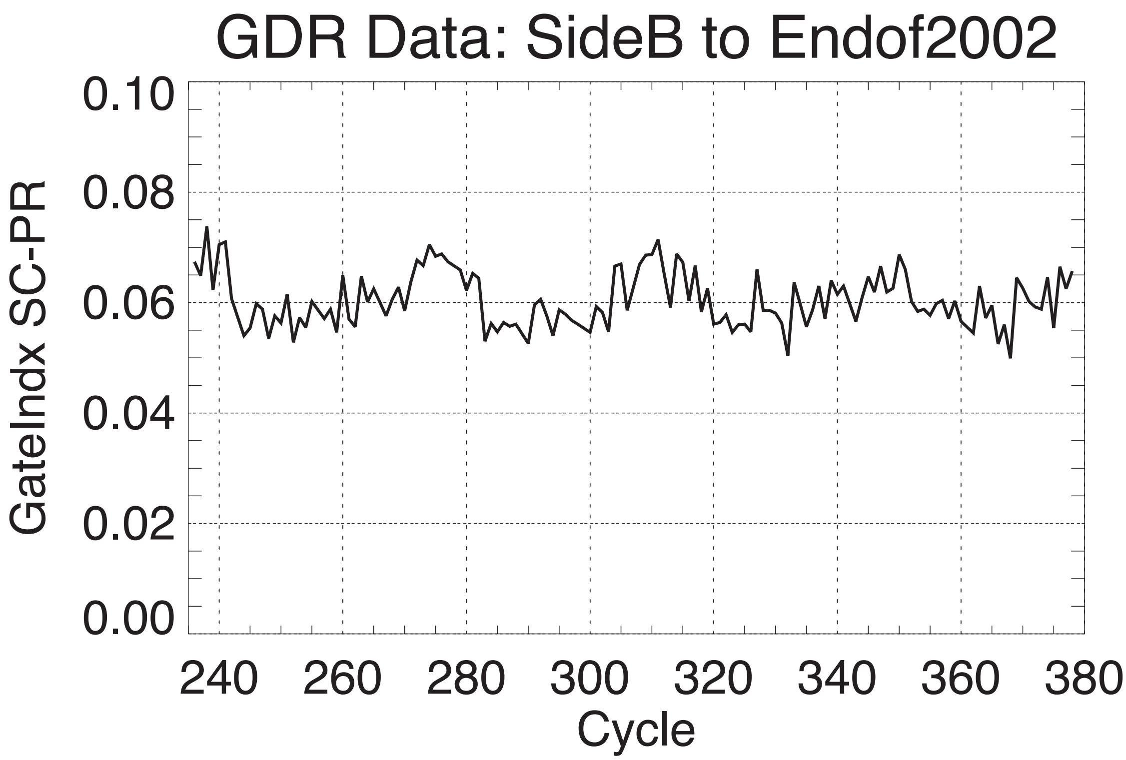

Figure 4-3 Cycle-Average Gate Index Delta

Figure 4-4 "Cycle-Average Sigma0 Delta in dB" plots the sigma0 difference, C-band minus Ku-band, from Side B turn-on to the end of year 2002. This plot provides a quick indication that the sigma0 calibration has been maintained to within 0.25 dB. Unlike the previous two figures, however, this figure is not a pure indication of system health, because both the Ku- and the C-band sigma0 calibrations have been adjusted during ground processing at the beginning of a number of different cycles throughout the TOPEX mission. For those few groups in the world using the sigma0 difference, relating it to rainfall estimation for instance, we strongly recommend that our TOPEX web site (topex.wff.nasa.gov) be visited. At that web site, we have provided a history of the sigma0 calibration changes as well as a possible set of sigma0 calibration adjustments to be applied to the distributed GDR sigma0 values.

Some of the relatively abrupt changes in Figure 4-4 are the result of various manual tweaking and adjustment of the sigma0 Cal Table throughout the TOPEX mission. Section 3.2 of this report discusses the TOPEX processing system’s Cal Table that

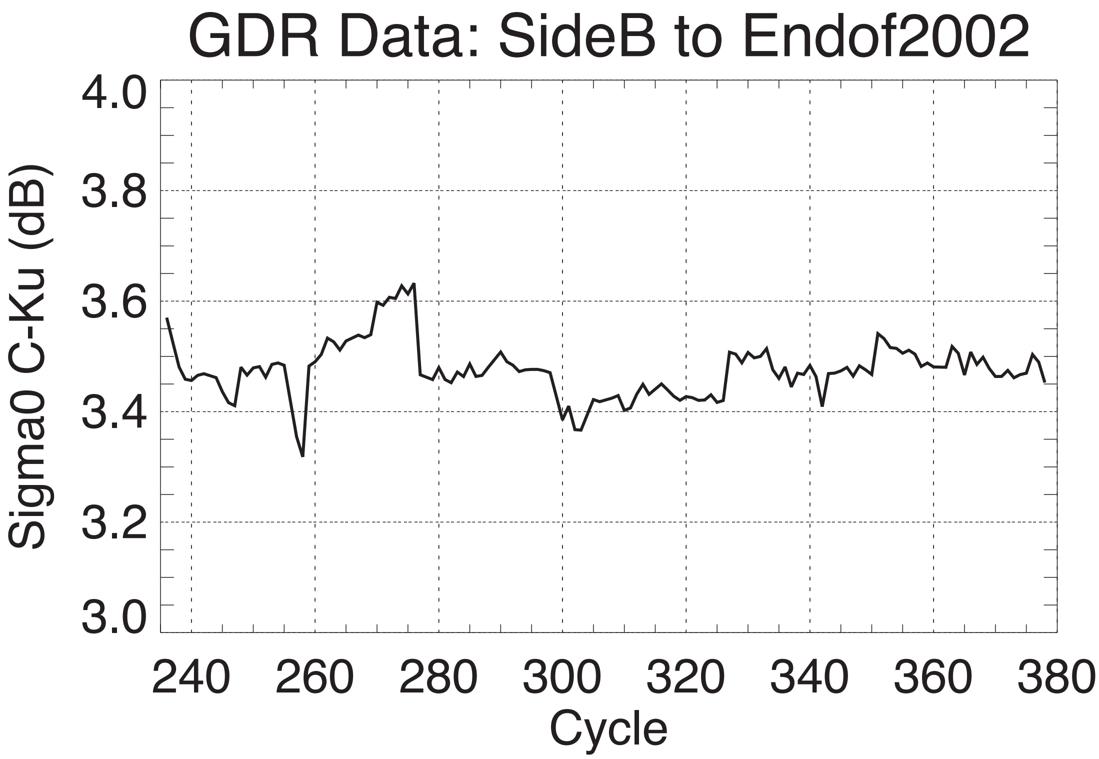

Figure 4-4 Cycle-Average Sigma0 Delta in dB

adjusts the sigma0 estimates for the effects of possible drifts or trends in the altimeter's power estimation. As discussed in that section, it is possible to reassess the trends and to produce an estimate of a "better guess" set of values that one might wish had it been used instead of the actual Cal Table values in the GDR production.

The Side A sigma0 calibration history and our current best estimate of Side A sigma0 adjustments is described in "TOPEX Sigma0 Calibration Table History for All Side A Data", by G.S. Hayne and D.W. Hancock III, July 27, 1999, available at our TOPEX documents web location http://topex.wff.nasa.gov/docs.html. An interim Side B calibration history and set of adjustments is available from "TOPEX Side B Sigma0 Calibration Table Adjustments: March 2002 Update", by G.S. Hayne and D.W. Hancock III, March 8, 2002, also available at http://topex.wff.nasa.gov/docs.html.

A set of cycle-by-cycle adjustments of the sigma0 difference (C- minus Ku-band) was obtained from the Side B calibration history documents just described, and these adjustments were applied to the sigma0 differences (as plotted in Figure 4-4) to produce the result shown in Figure 4-5. Figure 4-5 plots the sigma0 difference (C minus Ku) based on our best current estimate of the values that should have been in the sigma0 Cal Table. Figure 4-5 appears somewhat smoother than Figure 4-4.

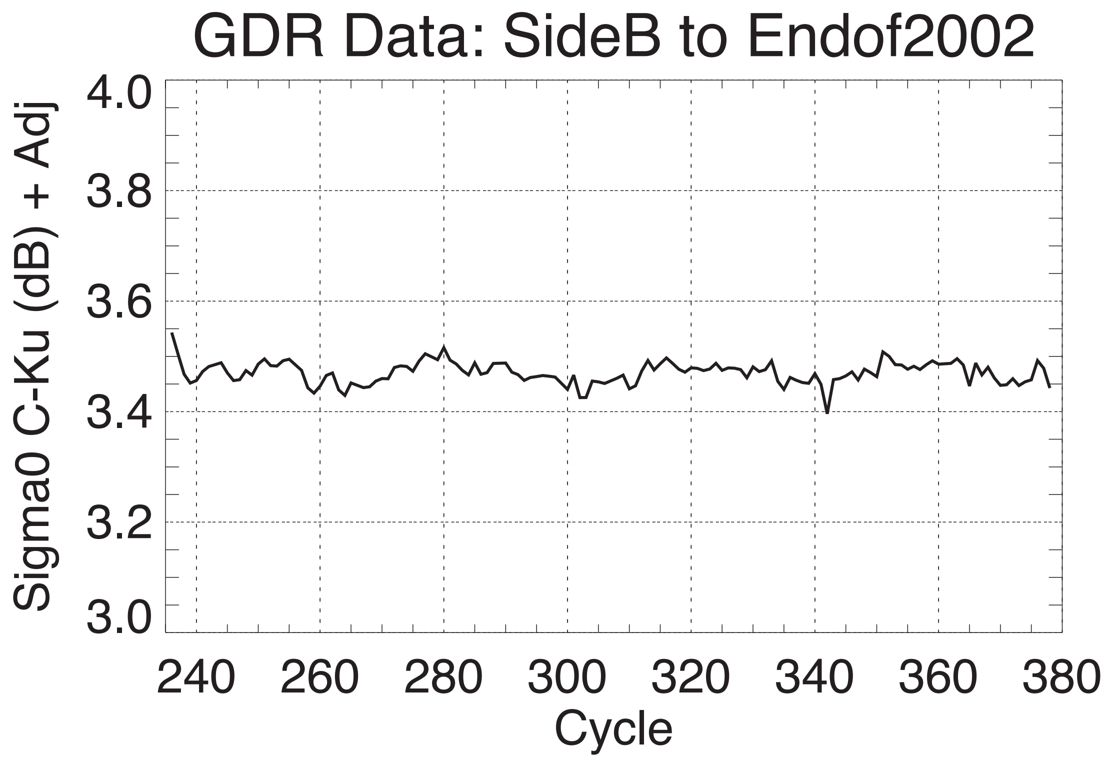

Figure 4-5 Cycle-Average Sigma0 Delta in dB with Cal Table Adjustment

4.3 Cal Mode Range Drift

Irregular oscillations (magnitude of several millimeters) of the CAL-1 Ku-Band range initially appeared on day 2002214 (August 2, 2002). A study of these anomalous oscillations has been undertaken by Wallops, the documentation of which appears in Appendix B.

4.4 Tape Recorder (TR) Degradation

Due to the effects of ageing, the capabilities of TOPEX's three onboard tape recorders, designated as TR-A, TR-B, and TR-C, have been in decline. Prior to the degradation in performance, the baseline number of Hours-in-Track in a 24-hour time period for Side B had been generally 23.85 hours per day, or 99.4%. The pre-launch goal for data acquisition was 90%.

In May 2000 (approximately 450 days since Side B turn-on), Tape Recorder B (TR-B) began to degrade, and the hours in track started dropping to about 23.40 hours. JPL OPS implemented procedures to augment data recovery by implementing realtime downloads. In September 2001 (approximately at 954 days), TR-B was removed from the recorder sequence. During this time, TR-A started to degrade and was eventually deactivated at the end of October 2002 (approximately at 1356 days). This left only one active recorder, TR-C, which is being augmented by realtime downloads.

With the availability of only one recorder, and with the realtime downloads, the number of hours-in-track ranged from 21.5 hours (89.6%) to 22.1 hours (92.1%). This is still within the pre-launch goal for data acquisition. Figure 4-6 provides the history trend of Hours-in-Track since the turn-on of Side B.

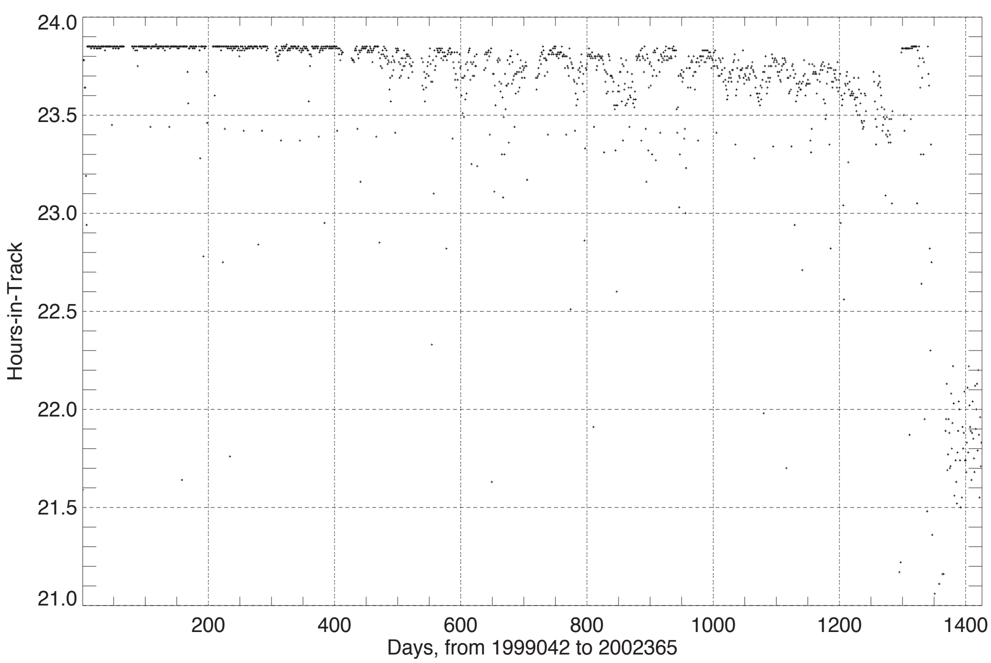

Figure 4-6 Hours-in-Track from Beginning of Side B

Section 5

TOPEX/POSEIDON Follow-On, JASON-1

JASON-1 is designated as the follow-on to TOPEX / Poseidon. Following its launch on December 7, 2001, JASON-1 was placed in a tandem orbit with TOPEX / Poseidon, in the same orbit and following TOPEX / Poseidon by only 72 seconds. The tandem lasted a total of 210 days (21 cycles), from January 15-August 15, 2002.

The tandem mission was followed by an orbital maneuver to transfer TOPEX / Poseidon to a different orbit, at the same altitude but with a ground track midway between the prior ground tracks.

Wallops has analyzed the JASON-1 GDR data both during and subsequent to the tandem mission, and has compared the JASON-1 performance with TOPEX. Some key results of these comparisons follow.

The JASON-1 data on the cycle summary plots which follow are extracted from the JASON Geophysical Data Record. The method of calculating conventions and editing criteria are per the AVISO and PODAAC Users Handbook, IGDR and GDR Jason Products, section 3.

5.1 Range Measurement Noise Comparison

The JASON-1 altimeter noise levels have been evaluated using a technique similar to the one for the TOPEX altimeter, as described in Section 4.2 of the "TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001, June 2001.

The noise level estimates provided in Table 5-1 are based on 1-minute track segments, and show stable characteristics from cycle-to-cycle with the basic linear dependence of the noise level upon significant wave height (SWH). The altimeter noise level for JASON-1 is estimated to be about 2.80 cm and for TOPEX, is estimated to be about 1.80 cm. These estimates are the average of all the cycles with each cycle having equal weight.

For a typical corresponding cycle, there are about 70% more JASON data points than TOPEX data points. This difference in the number of data points is attributed to: (a) the aging of the TOPEX data tape recorders, resulting in lost data; and (b) different editing criteria.

Table 5-1 JASON/TOPEX Range Measurement Noise Comparison

JASON CYCLE	JASON # PTS	JASON MEAN NL (cm)	JASON NL at 2m (cm)	DELTA MEAN NL JAS-TPX (cm)	DELTA NL at 2 JAS-TPX (cm)	TOPEX NL at 2m (cm)	TOPEX MEAN NL (cm)	TOPEX # PTS	TOPEX CYCLE
2				0.000	0.000	1.777	2.802	3213	345
3	5217	3.145	2.797	0.288	1.008	1.789	2.857	3364	346
4	5186	3.114	2.804	0.365	0.993	1.811	2.749	3314	347

Table 5-1 JASON/TOPEX Range Measurement Noise Comparison (Continued)

JASON CYCLE	JASON # PTS	JASON MEAN NL (cm)	JASON NL at 2m (cm)	DELTA MEAN NL JAS-TPX (cm)	DELTA NL at 2 JAS-TPX (cm)	TOPEX NL at 2m (cm)	TOPEX MEAN NL (cm)	TOPEX # PTS	TOPEX CYCLE
5	5174	3.028	2.798	0.380	0.995	1.803	2.648	3036	348
6	4944	3.100	2.768	0.350	0.983	1.785	2.750	3232	349
7	5237	3.216	2.828	0.301	1.038	1.790	2.915	3044	350
8	137	3.558	2.954	0.607	1.171	1.783	2.951	3064	351
9	5139	3.222	2.842	0.349	1.051	1.791	2.873	3114	352
10	5296	3.203	2.827	0.278	1.036	1.791	2.925	3105	353
11	5106	3.157	2.779	0.236	0.998	1.781	2.921	3107	354
12	3456	3.208	2.813	0.318	1.022	1.791	2.890	3195	355
13	3000	3.149	2.807	0.295	1.019	1.788	2.854	2976	356
14	5271	3.207	2.814	0.176	1.003	1.811	3.031	3081	357
15	4919	3.204	2.812	0.329	1.024	1.788	2.875	3192	358
16	5156	3.215	2.804	0.242	1.041	1.763	2.973	3253	359
17	5287	3.269	2.791	0.196	1.010	1.781	3.073	3172	360
18	5230	3.219	2.802	0.000	0.000				361
19	5031	3.214	2.813	0.231	1.021	1.792	2.983	2886	362
20	5411	3.303	2.827	0.082	1.026	1.801	3.221	3073	363
21	5420	3.249	2.794	0.151	1.017	1.777	3.098	3171	364
22	4956	3.305	2.854	0.232	1.090	1.764	3.073	2550	365
23	4863	3.124	2.824	0.224	1.063	1.761	2.900	2368	366
24	4903	3.150	2.799	0.230	1.006	1.793	2.920	3226	367
25	4905	3.146	2.802	0.267	1.016	1.786	2.879	2950	368
26	4909	3.074	2.815	0.183	1.028	1.787	2.891	2519	369
27	4821	3.113	2.809	0.283	1.013	1.796	2.830	2881	370
28	4874	3.148	2.810	0.204	1.020	1.790	2.944	2338	371
29	4779	3.086	2.825	0.268	1.016	1.809	2.818	2218	372
30	4763	3.045	2.767	0.377	0.956	1.811	2.668	2777	373
31	4878	3.100	2.735	0.231	0.950	1.785	2.869	3247	374
32	4200	3.049	2.737	0.309	0.970	1.767	2.740	2858	375
33	4758	3.132	2.737	0.164	0.968	1.769	2.968	2961	376
34	4833	3.131	2.782	0.329	1.011	1.771	2.802	2830	377
35	4802	3.015	2.755	0.313	0.962	1.793	2.702	2961	378

5.2 Significant Wave Height (SWH) Comparison

The per-cycle JASON-1 and TOPEX SWH Ku estimates, based on 60-second averages, are provided in Table 5-2. The JASON-1 SWH Ku average of all the cycles is 2.68

m and the average SWH Ku for TOPEX is 2.83 m, a difference of 0.15 m. The JASON-1 SWH C averages of all the cycles is 2.69 m and the average SWH C for TOPEX is 2.88 m, a difference of 0.19 m. Figure 5-1 depicts the per-cycle difference between the JASON-1 and TOPEX SWH, for both Ku-Band and C-Band.

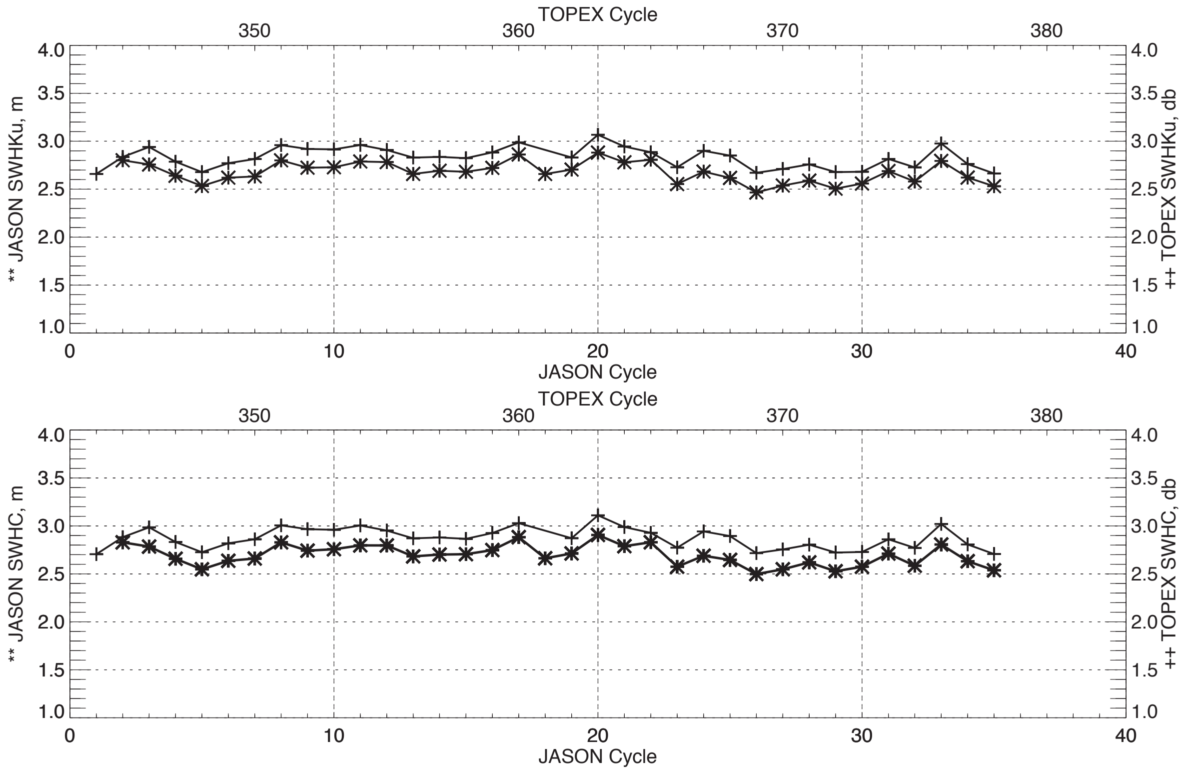

Figure 5-1 JASON/TOPEX Significant Wave Height Comparison

Table 5-2 JASON/TOPEX Ku-Band Significant Wave Height Comparison

JASON CYCLE	JASON #PTS	JASON SWH Ku (m)	DELTA SWH JAS-TPX (m)	TOPEX SWH Ku (m)	TOPEX # PTS	TOPEX CYCLE
2	77609	2.8015	-0.0350	2.8365	383335	345
3	425502	2.7578	-0.1826	2.9404	382620	346
4	421376	2.6395	-0.1468	2.7863	383864	347
5	420407	2.5334	-0.1445	2.6779	376889	348
6	400755	2.6201	-0.1514	2.7715	379086	349
7	425630	2.6328	-0.1816	2.8144	374851	350
8	425696	2.8008	-0.1589	2.9597	381516	351
9	382775	2.7237	-0.1957	2.9194	375937	352

Table 5-2 JASON/TOPEX Ku-Band Significant Wave Height Comparison (Continued)

JASON CYCLE	JASON #PTS	JASON SWH Ku (m)	DELTA SWH JAS-TPX (m)	TOPEX SWH Ku (m)	TOPEX # PTS	TOPEX CYCLE
10	427309	2.7284	-0.1867	2.9151	347822	353
11	411023	2.7887	-0.1719	2.9606	371638	354
12	266049	2.7830	-0.1251	2.9081	368603	355
13	278226	2.6587	-0.1707	2.8294	356896	356
14	412478	2.6921	-0.1449	2.8370	344142	357
15	376587	2.6813	-0.1422	2.8235	350906	358
16	388582	2.7220	-0.1621	2.8841	345711	359
17	392419	2.8623	-0.1260	2.9883	342964	360
18	381733	2.6585	2.6585			361
19	367866	2.7041	-0.1265	2.8306	328623	362
20	352523	2.8818	-0.1855	3.0673	330061	363
21	396634	2.7799	-0.1650	2.9449	323485	364
22	360479	2.8068	-0.0787	2.8855	271951	365
23	364190	2.5530	-0.1754	2.7284	234238	366
24	366943	2.6832	-0.2168	2.9000	333135	367
25	363212	2.6174	-0.2330	2.8504	307603	368
26	365303	2.4655	-0.2056	2.6711	318448	369
27	359198	2.5375	-0.1736	2.7111	293671	370
28	365317	2.5896	-0.1690	2.7586	261881	371
29	362364	2.5051	-0.1728	2.6779	254943	372
30	350944	2.5589	-0.1231	2.6820	296394	373
31	360164	2.6892	-0.1263	2.8155	310105	374
32	317067	2.5801	-0.1480	2.7281	300341	375
33	364413	2.7945	-0.1819	2.9764	319109	376
34	368868	2.6212	-0.1407	2.7619	321233	377
35	357969	2.5309	-0.1332	2.6641	325668	378

5.3 Sigma Naught Comparison

The per-cycle JASON-1 and TOPEX Ku-Band Sigma0 estimates, based on 60-second averages, are provided in Table 5-3. The JASON-1 Ku Sigma0 average is 11.44 dB, and the Ku Sigma0 average for TOPEX is 11.17 dB, a difference of 0.27 dB. The C Sigma0 average for JASON is 15.17 dB, and the C Sigma0 average for TOPEX is 14.66 dB, a difference of 0.51 dB, and again the JASON-1 value is larger. Figure 5-2 shows the per-cycle difference between the JASON-1 and TOPEX sigma0, for both Ku-Band and C-Band.

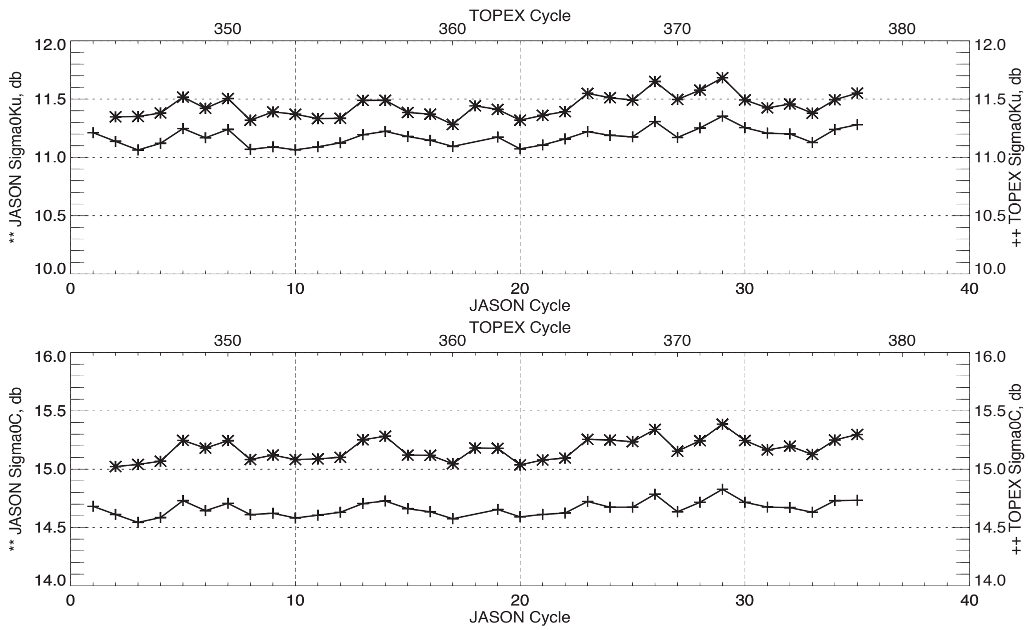

Figure 5-2 JASON/TOPEX Sigma Naught Comparison

Table 5-3 JASON/TOPEX Ku-Band Sigma0 Estimates

JASON CYCLE	JASON # PTS	JASON SIGMA0 Ku (dB)	DELTA SIGMA0 JAS-TPX (dB)	TOPEX SIGMA0 Ku (dB)	TOPEX # PTS	TOPEX CYCLE
2	77609	11.3474	0.2099	11.1375	383335	345
3	425502	11.3507	0.2872	11.0635	382620	346
4	421376	11.3805	0.2595	11.1210	383864	347
5	420407	11.5167	0.2697	11.2470	376889	348
6	400755	11.4211	0.2530	11.1681	379086	349
7	425630	11.5046	0.2648	11.2398	374851	350
8	425696	11.3190	0.2497	11.0693	381516	351
9	382775	11.3901	0.3005	11.0896	375937	352
10	427309	11.3702	0.3049	11.0653	347822	353
11	411023	11.3326	0.2420	11.0906	371638	354

Table 5-3 JASON/TOPEX Ku-Band Sigma0 Estimates

JASON CYCLE	JASON # PTS	JASON SIGMA0 Ku (dB)	DELTA SIGMA0 JAS-TPX (dB)	TOPEX SIGMA0 Ku (dB)	TOPEX # PTS	TOPEX CYCLE
12	266049	11.3354	0.2109	11.1245	368603	355
13	278226	11.4891	0.2948	11.1943	356896	356
14	412478	11.4895	0.2664	11.2231	344142	357
15	376587	11.3851	0.2059	11.1792	350906	358
16	388582	11.3708	0.2244	11.1464	345711	359
17	392419	11.2823	0.1883	11.0940	342964	360
18	381733	11.4421				361
19	367866	11.4112	0.2375	11.1737	328623	362
20	352523	11.3189	0.2455	11.0734	330061	363
21	396634	11.3606	0.2541	11.1065	323485	364
22	360479	11.3928	0.2351	11.1577	271951	365
23	364190	11.5489	0.3283	11.2206	234238	366
24	366943	11.5115	0.3229	11.1886	333135	367
25	363212	11.4912	0.3151	11.1761	307603	368
26	365303	11.6507	0.3434	11.3073	318448	369
27	359198	11.4969	0.3261	11.1708	293671	370
28	365317	11.5768	0.3242	11.2526	261881	371
29	362364	11.6832	0.3303	11.3529	254943	372
30	350944	11.4925	0.2377	11.2548	296394	373
31	360164	11.4246	0.2169	11.2077	310105	374
32	317067	11.4578	0.2566	11.2012	300341	375
33	364413	11.3792	0.2518	11.1274	319109	376
34	368868	11.4940	0.2539	11.2401	321233	377
35	357969	11.5511	0.2707	11.2804	325668	378

5.4 Sigma Naught vs. Significant Wave Height Comparison

The upper plot in Figure 5-3 depicts TOPEX and JASON-1 Sigma0 for Ku-Band vs. the corresponding SWH. The lower plot in Figure 5-3 is similar except that it is for C-Band. In both plots, except for the Sigma0 and SWH biases between the two altimeter systems, the relationship of Sigma0 to SWH is nearly identical.

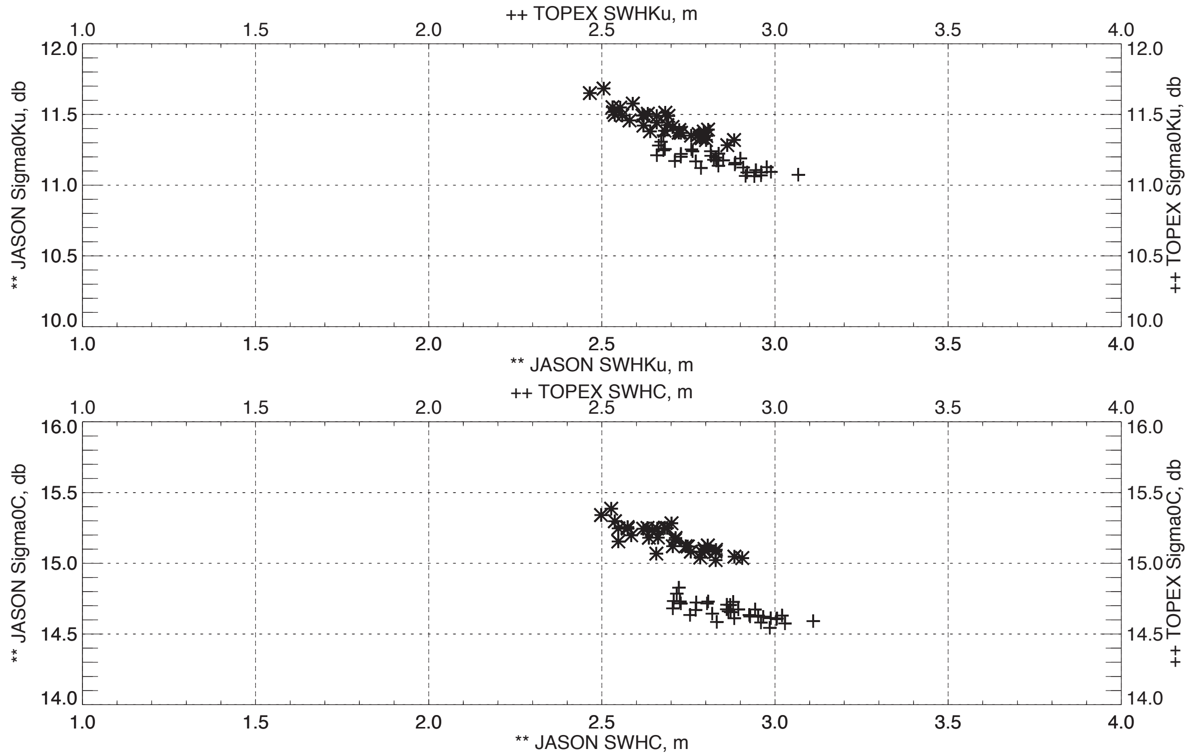

Figure 5-3 JASON/TOPEX Sigma0 vs. SWH Comparison

5.5 Sea Level Anomaly Comparison

Sea level anomalies, also called residual sea surface heights, have been calculated for both altimeters by subtracting previously-unmodeled tides, mean sea surface, and barometric effects from the GDR-provided sea surface heights. The JASON-1 sea level anomaly average of all the cycles is 0.1296 meters and the average residual sea surface height for TOPEX is 0.0091 meters.The results are shown in Figure 5-4. During the 21-cycles of tandem operations, the JASON-1 sea level anomalies are approximately 12 cm higher than TOPEX. Subsequent to the tandem operations, the differences have increased slightly, to about 13 cm.

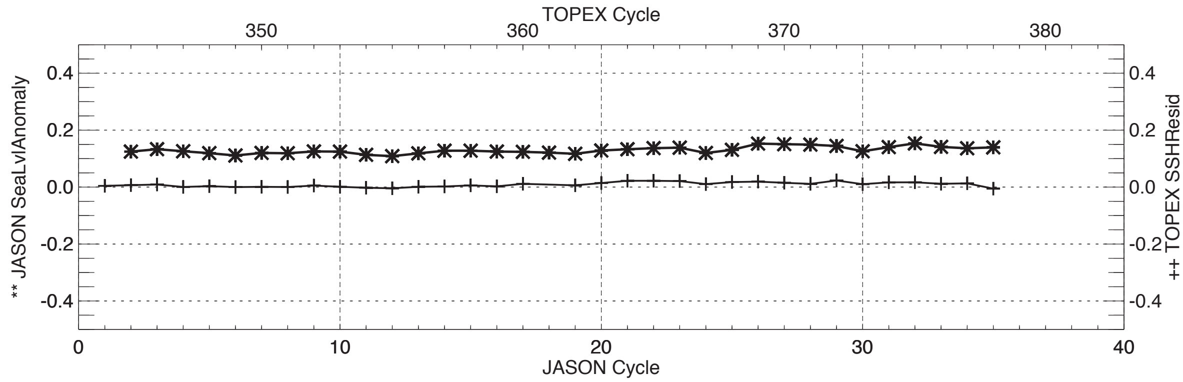

Figure 5-4 JASON/TOPEX Sea Level Anomaly Comparison

Table 5-4 JASON/TOPEX Sea Level Anomaly Comparison

JASON CYCLE	JASON #PTS	JASON SeaLvlAnom (m)	DELTA JAS-TPX (m)	TOPEX SSHRes (m)	TOPEX # PTS	TOPEX CYCLE
2	77609	0.1247	0.1178	0.0069	383335	345
3	425502	0.1331	0.1241	0.0090	382620	346
4	421376	0.1259	0.1255	0.0004	383864	347
5	420407	0.1191	0.1158	0.0033	376889	348
6	400755	0.1111	0.1110	0.0001	379086	349
7	425630	0.1199	0.1191	0.0008	374851	350
8	425696	0.1189	0.1186	0.0003	381516	351
9	382775	0.1252	0.1199	0.0053	375937	352
10	427309	0.1246	0.1236	0.0010	347822	353
11	411023	0.1134	0.1157	-0.0023	371638	354
12	266049	0.1087	0.1130	-0.0043	368603	355
13	278226	0.1184	0.1174	0.0010	356896	356
14	412478	0.1279	0.1258	0.0021	344142	357
15	376587	0.1278	0.1219	0.0059	350906	358
16	388582	0.1248	0.1222	0.0026	345711	359
17	392419	0.1237	0.1122	0.0115	342964	360
18	381733	0.1210	0.1210			361
19	367866	0.1169	0.1108	0.0061	328623	362
20	352523	0.1284	0.1142	0.0142	330061	363

Table 5-4 JASON/TOPEX Sea Level Anomaly Comparison (Continued)

JASON CYCLE	JASON #PTS	JASON SeaLvlAnom (m)	DELTA JAS-TPX (m)	TOPEX SSHRes (m)	TOPEX # PTS	TOPEX CYCLE
21	396634	0.1330	0.1108	0.0222	323485	364
22	360479	0.1368	0.1147	0.0221	271951	365
23	364190	0.1384	0.1174	0.0210	234238	366
24	366943	0.1198	0.1093	0.0105	333135	367
25	363212	0.1308	0.1132	0.0176	307603	368
26	365303	0.1527	0.1336	0.0191	318448	369
27	359198	0.1508	0.1357	0.0151	293671	370
28	365317	0.1491	0.1378	0.0113	261881	371
29	362364	0.1445	0.1213	0.0232	254943	372
30	350944	0.1257	0.1155	0.0102	296394	373
31	360164	0.1404	0.1237	0.0167	310105	374
32	317067	0.1536	0.1368	0.0168	300341	375
33	364413	0.1412	0.1270	0.0142	319109	376
34	368868	0.1363	0.1237	0.0126	321233	377
35	357969	0.1396	0.1348	0.0048	325668	378

Section 6

Engineering Assessment Synopsis

6.1 Performance Overview

Side B of the TOPEX NASA Radar Altimeter (NRA) was turned on, for the first time in space, on February 11, 1999. This followed six-and-a-half years of very successful on-orbit operations by Side A. Side A was turned off due to its Point Target Response having changed slightly over time, affecting measurement consistency. Side B is now the operational altimeter; however, Side A could be turned back on if needed.

Side A performance significantly surpassed all its pre-launch specifications, including its length of service. Based on our performance analysis and based on the reports of science investigators, Side B is performing as well as, or perhaps even better than, Side A.

The amount of ground-collected TOPEX NRA data on a daily basis has been diminished by the performance degradation of the onboard tape recorders, but the collection level is still at or above the pre-launch goal of 90%.

The successful launch of Jason-1 occurred on December 7, 2001, and its performance appears within specification and to be stable. Some of the techniques we have used on the TOPEX NRA are being applied to Jason-1 for limited amounts of data.

The TOPEX NRA Cal mode range has started showing oscillations and has been documented in several sections of this report. At this time, we do not have a concern relative to the instrument, but this calibration range oscillation may have minor performance effects, at the few-millimeter level, on the data.

The TOPEX NRA completed its orbit maneuver transfer to its desired new orbit during cycle 368. To date we have not noticed any significant changes in instrument performance. Global statistics remain consistent with previous years.

We are continuing our TOPEX NRA performance assessment of Side B on a daily basis.

Appendix A

Accumulative Index of Studies

Side B Point Target Response - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2002*, March 2002.

Ancillary Performance Assessment Results, using the Differencing of the Ku-Band and C-Band Data - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2002*, March 2002.

Assessment of the Cycle-by-Cycle TOPEX Altimeter Range Measurement Noise Level by High-Pass Filtering 1-Hz Data - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2002*, March 2002.

Land-to-Water Acquisition Times - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2002*, March 2002.

Attitude Anomaly - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2002*, March 2002.

Side B Point Target Response - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Ancillary Performance Assessment Results, using the Differencing of the Ku-Band and C-Band Data - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Possible Drift in the Radar-derived Ionospheric Corrections for TOPEX - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Assessment of the Cycle-by-Cycle TOPEX Altimeter Noise Level by High-Pass Filtering 1-Hz Data - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Land-to-Water Acquisition Times - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Attitude Anomaly - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2001*, June 2001.

Side B Point Target Response - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2000*, September 2000.

Land-to-Water Acquisition Times - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2000*, September 2000.

Transition to Side B - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Side B Turn-On to January 1, 2000*, September 2000.

Side A Point Target Response Changes and Consequences - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Internal calibrations - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Cycle Summaries - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Key Events - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Engineering Monitors - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999*, August 1999.

Launch-to-Date Waveform Monitoring - *TOPEX Radar Altimeter Engineering Assessment Report, Update: From Launch to Turn-Off of Side A on February 10, 1999, August 1999*.

Oscillator Drift Algorithm Change (Update) - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1998*, June 1998.

AGC and Range Corrections During the 1997 ASTRA Event - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1998*, June 1998.

C-Band Power Drop - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Oscillator Drift Algorithm Change - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Seasonal Distribution of Sigma-0 Blooms - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Effects of Coastlines - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

TOPEX Altimeter 1996d362t 12:55 Side B C MTU Transmit Anomaly - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

TOPEX C Band Received Power Study Results - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1997*, March 1997.

Sea Surface Height Residuals as Indicators of Global Sea Level Change - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1996*, May 1996.

Over-Land Losses of Lock: Seasonal Variations - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1996*, May 1996.

Range Corrections for the Effects of Waveform Leakage - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1996*, May 1996.

Waveform Leakage Range Correction - *TOPEX Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1996*, May 1996.

Sigma0 Error Effect on Range - *TOPEX Mission Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1995*, March 1995.

CAL2 Differences Over Water and Land - *TOPEX Mission Radar Altimeter Engineering Assessment Report, Update: Launch to January 1, 1995*, March 1995.

Waveform Samples Assessment - *TOPEX Mission Radar Altimeter Engineering Assessment Report*, February 1994.

Appendix B
TOPEX Side B Cal Mode Range Studies

The following three sections, B.1 through B.3, reproduce text and figures from three separate memos by G.S. Hayne and D.W. Hancock III discussing the TOPEX Side B Cal Mode Range drift which first appeared in cycle 364 and persisted beyond the end of year 2002. In section B.1, the first memo (whose date was August 15, 2002) described the first appearance of the range drift early in cycle 364 and claimed that after a downward step of about a half centimeter the Cal mode Range seemed to have stabilized at the new lower value. In Section B.2, the second memo (whose date was September 5, 2002) indicated that the first memo was incorrect in asserting a stable lower Cal Mode Range but that the Cal Mode Range had returned to its original levels of before cycle 364. In section B.3, the third memo (dated January 16, 2003) reported that the first two memos were both incorrect and that the Cal Mode Range was continuing to meander within approximately 6 millimeter bounds.

All three memos are supplied here as part of TOPEX history, but the reader should note that the first memo (Section B.2) is superseded by the second memo (Section b.2) which, in turn, is superseded by the third memo (Section B.3). Thus it should be necessary only to read the third memo (Section B.3) for a summary of the Cal Mode Range meandering from cycle 364 through the end of year 2002.

B.1 Discussion of TOPEX Side B Cal Mode Range Drift in Cycle 364 (August 15, 2002)

We discuss here a drift recently observed in the TOPEX altimeter's internal calibration mode range measurement. The calibration mode has two submodes and in the first of these submodes, referred to as Cal Mode 1 or CAL-1, the altimeter internally tracks a delayed and attenuated portion of its transmitted pulse. This CAL-1 range measurement is intended to detect possible drifts in the altimeter's timing. There are 16 separate steps within CAL-1, each step having a different AGC (power) level; our analyses and summaries have concentrated on step 5 which has an AGC level close to that of typical over-ocean normal tracking operation. For this paper we will present only the results from step 5 of CAL-1. The Cal Mode has been executed twice per day over the entire TOPEX operation, and we have provided monthly updates to the CAL-1-derived range stability estimates at http://topex.wff.nasa.gov/docs/RangeStabUpdate.html.

Figure B-1 "TOPEX Combined (Ku & C) Delta Range from CAL-1 Step 5" on page -2 presents the TOPEX cycle averages of the CAL-1-derived delta ranges for the combined Ku-and C-band result. "Combined" refers to the weighted sum of Ku- and C-band results which eliminates path delays due to the ionospheric electron content, and "delta range" refers to the CAL-1 range after subtraction of an arbitrary but constant reference value. The last data cycle in Figure B-1 is 364, and its Cal Mode combined delta range is significantly lower than any other TOPEX Side B cycle.

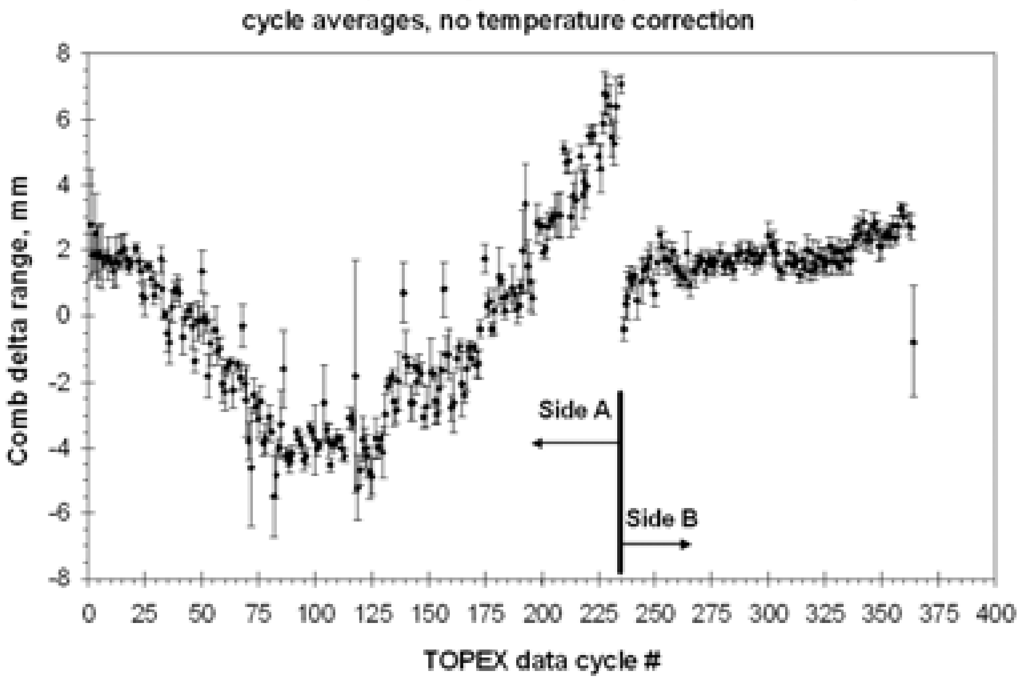

Figure B-1 TOPEX Combined (Ku & C) Delta Range from CAL-1 Step 5

Each of the cycle averages in Figure B-1 is the result of about twenty individual Cal Modes, and Figure B-2 "TOPEX Side B Full-Rate Combined (Ku & C) Delta Range" on page -2 presents the full-rate Cal Mode combined ranges for Side B only. Notice that the Figure B-2 horizontal axis is days relative to the start of Side B operation, not cycle number. The last Cal Mode plotted in Figure B-2 was from 2002 day 226.

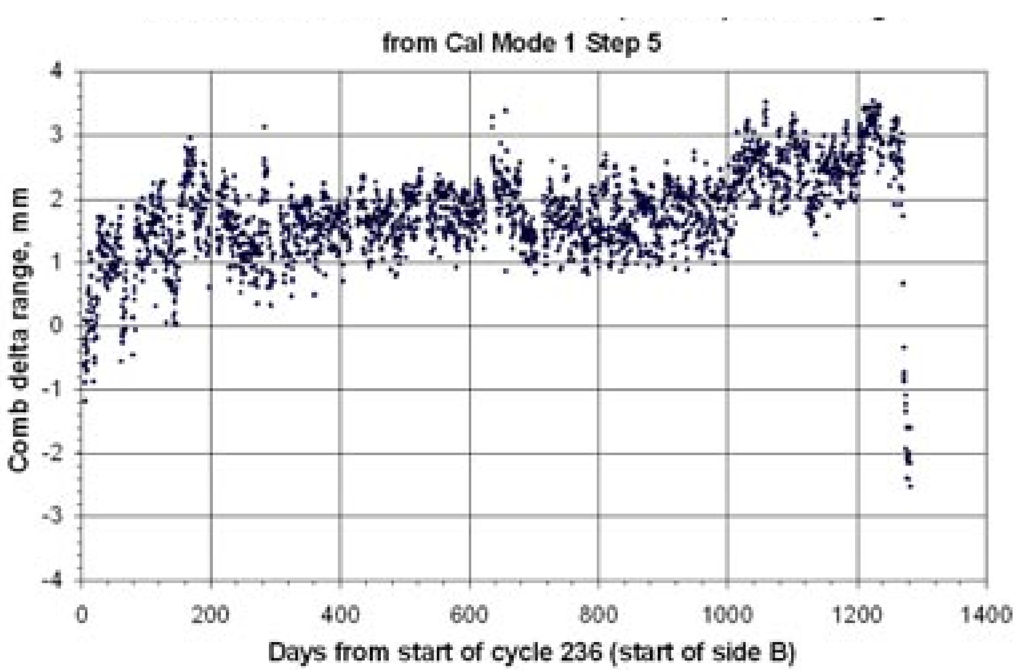

Figure B-2 TOPEX Side B Full-Rate Combined (Ku & C) Delta Range

Our immediate concern is with the last two dozen or so CAL Mode delta ranges shown at the rightmost part of Figure B-2. These CAL-1 combined delta ranges show a relatively sudden decrease of about 5 millimeters, and nothing like this sharp change has been seen anywhere else in the Side B operation.

Figure B-3 "TOPEX Side B Full-Rate Combined (Ku & C) Delta Range" on page -3 shows just the last 30 days or so of Figure B-3. A rough characterization of Figure B-3 is: 1) the CAL-1 combined range is approximately stable through the second CAL Mode of 2002 day 213; 2) this range decreases over the next six days; and then 3) the CAL-1 combined range has a new approximately stable value starting with the second CAL Mode of 2002 day 219. The final lower stable value is approximately 5 mm lower than the initial stable value in Figure B-3.

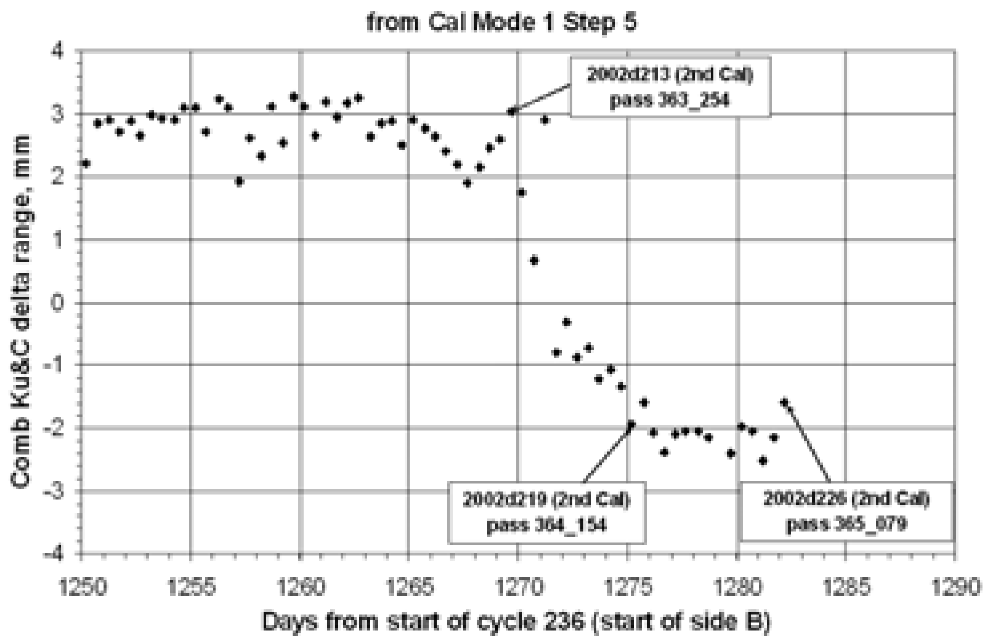

Figure B-3 TOPEX Side B Full-Rate Combined (Ku & C) Delta Range

Our Figures have concentrated on the combined (Ku & C) CAL-1 range change, because it is the combined range that is of interest to the end user of the TOPEX data. This CAL-1 combined range change is almost entirely due to a change in the CAL-1 Ku-band range, and the CAL-1 C-band range has very little if any change over the time of the Ku-band change.

We have searched in all the temperatures, voltages, currents, and powers which are monitored in the TOPEX engineering mode data, and we have been unable to find any parameters which seem to be correlated with the CAL-1 range change reported here. We have seen no significant changes in the altimeter’s point target response (effectively, the transmitted pulse shape as observed by the receiver) which is monitored monthly by execution of a special calibration sweep (CalSweep) mode. The latest regularly scheduled CalSweep occurred on 2002 day 213. We requested an additional CalSweep which was executed on 2002 day 223, and we found no significant changes in that CalSweep from any of the other recent CalSweeps.

We note that the magnitude of the recent CAL-1 range change is only half a centimeter so it is the rate of the change, not the magnitude, which we find puzzling. For now we can only wait, continue to monitor closely the altimeter data, and hope that the new CAL-1 range apparent stability continues.

B.2 Discussion of TOPEX Side B Cal Mode Range Drift from Cycles 364 to 366 (September 6, 2002)

Introduction

In mid-August 2002 we described an apparent drift observed in the TOPEX altimeter's internal calibration mode's range measurement in the brief report "Discussion of TOPEX Side B Cal Mode Range Drift in Cycle 364", G. S. Hayne and D. W. Hancock III, August 15, 2002 (available at http://topex.wff.nasa.gov/docs/CALl-dht.pdf). We reported then that the calibration mode combined (Ku & C) delta range had made a relatively sudden downward step of about 5 mm in the first half of cycle 364 and then was continuing at the new apparently stable value. The combined delta range change was almost entirely due to a change in the Ku-band CAL-1 delta range.

With another three weeks of data in hand since August 15, we now see that the CAL-1 combined delta range has not stayed at the 5 mm low value but has returned almost to the vicinity of its values prior to cycle 364. The combined CAL-1 delta range changes continue to be due almost entirely to Ku-band CAL-1 delta range changes. We will describe the recent changes that have occurred since our August 15 report. The reader should see that earlier report for a description of the TOPEX altimeter's calibration mode and our use of the term CAL-1. Today's report is again restricted to data from Step 5 of Cal Mode 1.

CAL-1 Delta Range Results

Figure B-4 "Side B Combined (Ku & C) Delta Range vs. Cycle" on page -6 presents the TOPEX cycle averages of the CAL-1-derived delta ranges for the combined Ku- and C-band result. "Combined" refers to the weighted sum of Ku- and C-band results which eliminates path delays due to the ionospheric electron content, and "delta range" refers to the CAL-1 range after subtraction of an arbitrary but constant reference value. The last data cycle in Figure B-4 is 366. There are about 20 individual CAL-1 results in each of the cycle averages in Figure B-4, and the error bars indicate the standard deviations in the averages.

Figure B-5 "Side B Full-Rate CAL-1 Comb. (Ku & C) dRange vs. Cycle" on page -6 presents the full-rate Cal Mode combined delta ranges for Side B only. The last CAL Mode data plotted in Figure B-5 was from 2002 day 247.

Our immediate concern is with the last two dozen or so Cal Mode delta ranges shown at the rightmost part of Figure B-5. These CAL-1 combined delta ranges show a relatively sudden decrease of about 5 millimeters in the first half of cycle 364, followed by an apparent partial recovery. The next figure will show an expanded view of the right hand part of Figure B-5.

Figure B-6 "Side B CAL-1 Step-5 Comb. (Ku & C) dRange vs. Cycle" on page -7 shows the full-rate Cal Mode combined ranges from cycle 354 through part of cycle 367. Remember that there are two Cal Modes executed per day, for a total of 20 Cal Modes per data cycle. A rough characterization of Figure B-6 is: 1) the CAL-1 combined range is approximately stable through the second Cal Mode of 2002 day 213; 2) this range decreases over the next six days; 3) for the following six days the range has a

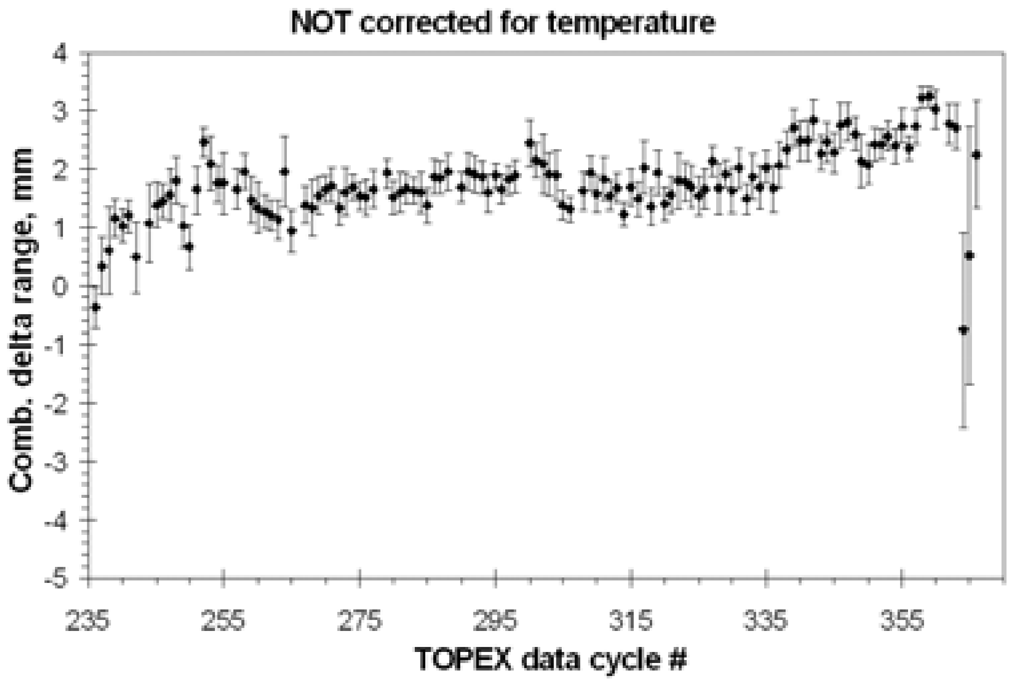

Figure B-4 Side B Combined (Ku & C) Delta Range vs. Cycle

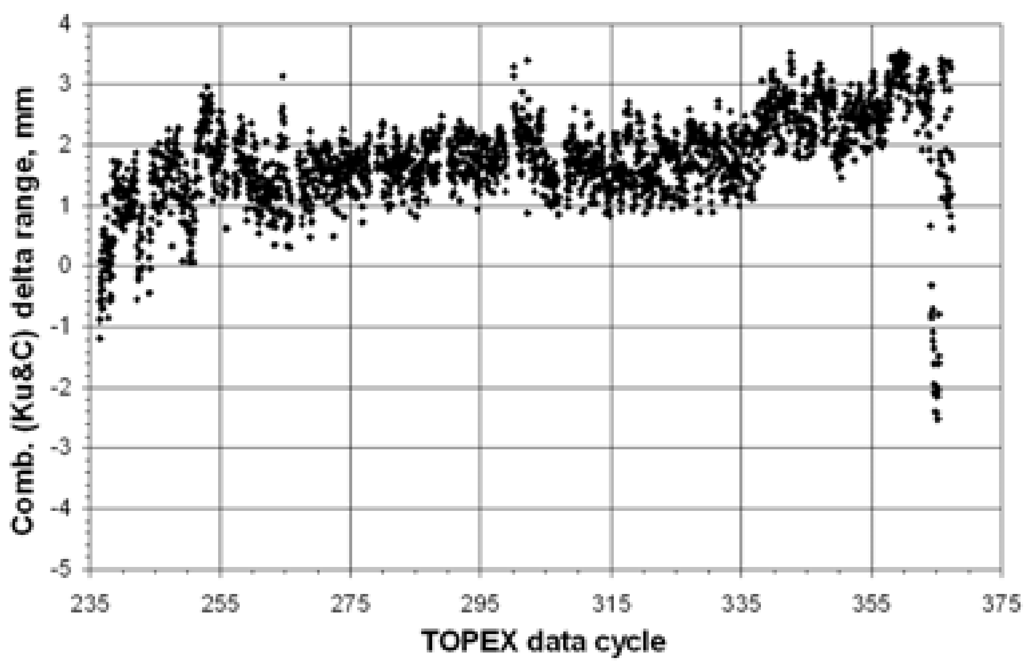

Figure B-5 Side B Full-Rate CAL-1 Comb. (Ku & C) dRange vs. Cycle

temporarily stable value (about 5 mm below the values from before cycle 364) starting with the second Cal Mode of 2002 day 219; 4) the combined range then tries to return to approximately its pre-cycle 364 value for several days; and 5) in the last two weeks the range still exhibits some uncertainty, bouncing around within 2 mm of its pre-cycle 364 value.

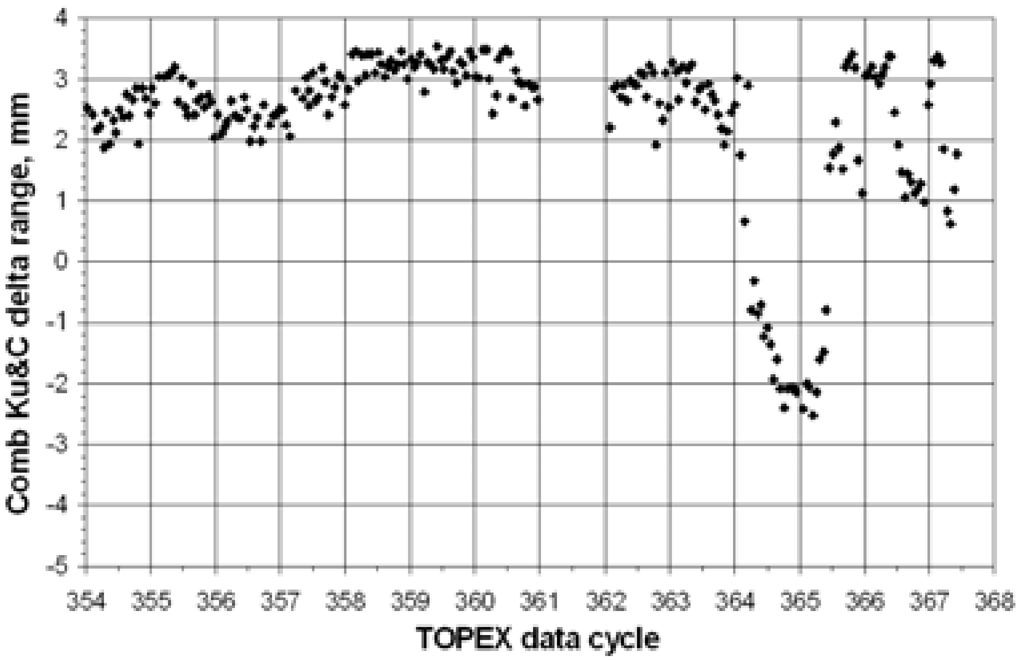

Figure B-6 Side B CAL-1 Step-5 Comb. (Ku & C) dRange vs. Cycle

Our Figures have concentrated on the combined (Ku & C) CAL-1 range change, because it is the combined range that is of interest to the end user of the TOPEX data. This CAL-1 combined range change is almost entirely due to a change in the CAL-1 Ku-band range, and the CAL-1 C-band range has very little if any change over the time of the Ku-band change.

Other investigations

We have seen no significant changes in the altimeter's point target response (PTR). The PTR is in effect the transmitted pulse shape as observed by the receiver, and through all of Side B operation the PTR has been monitored by execution of a special calibration sweep (CalSweep) mode approximately once per month. After the appearance of the CAL-1 range change in cycle 364, the frequency of the CalSweeps has been increased and a CalSweep is now executed once every 10-day data cycle. The latest CalSweep occurred on 2002 day 243, and we found no significant changes in that CalSweep's PTR compared to the PTR from any of the other recent CalSweeps.

A CalSweep starts as a regular Cal Mode, and the first four AGC steps proceed normally with about 10 seconds of data in each step. About 3-4 seconds into the fifth AGC step the altimeter's normal CAL Mode tracking is interrupted and the fine height is stepped through its entire range several times in a procedure lasting several minutes. From the first several seconds of CAL-1 Step 5 there is a normal CAL-range available. We have always deleted that CAL-1 range from our CAL-1 range data sets because all other CAL-1 ranges are based on about 10 seconds of data while the CAL-1 range from a CAL Sweep is based only on three seconds or so of data. Therefore Figure B-4 through Figure B-6 do not include the CAL-1 Step 5 results from any CalSweeps.

As we said in our 15 August 2002 report, we have searched in all the temperatures, voltages, currents, and powers which are monitored in the TOPEX engineering mode data, and did not find any parameters strongly correlated with the CAL-1 range changes reported here. We have looked back at CAL-1 ranges in previous CalSweeps and found that on occasion the Step 5 (and Steps 1 - 4) ranges were approximately down about 5 mm. Also for the CAL Sweep on 2002 day 223, the CAL-1 range was up about 5 mm (near normal) during the period of time that the rest of the CAL-1 ranges were low.

During the period of the 5 mm low CAL-1 ranges in cycle 364, we did find a very minor change in the +15 volt readings. This small change is shown in Figure B-7 "TOPEX side B +15V Monitor vs. Cycle" on page -9 which plots our engineering database's maximum, mean, and minimum values of the +15 volt monitor. Each database value represents 30 minutes of TOPEX engineering data (such as voltages) which are in the telemetry data about once every 8 seconds. The change at cycle 361 is expected because the CNES altimeter was on for that cycle. Look, however, at the plotted minimum values shortly after the start of cycle 364. These higher minima represent a single bit change from the values seen in the rest of the Side B history. This is the only time in Side B that we have seen this one-bit change in the +15 V monitor values in our database. We do not believe one-bit change is the cause of the range change but it might conceivably indicate something different in the altimeter's thermal environment. We know, from the altimeter's pre-launch thermal vacuum testing, that temperature changes could cause some changes in CAL Mode. Prior to a CAL Sweep the altimeter is placed in idle mode for a few minutes while a software patch is being loaded, and this can slightly change the thermal gradients within the altimeter. At this point we believe that thermal gradient changes might be one cause for our observations that 1) in the "normal" history of Side B prior to cycle 364, some CalSweeps (but not all) had low associated CAL-1 ranges while all other CAL-1 ranges were normal, and 2) during the anomalously low (by 5 mm) CAL-1 ranges in cycle 364, the CAL-1 range during a CAL Sweep was "normal". All the individual altimeter temperature values lie within ranges that have already been seen during the normal behavior of Side B. Since nothing abnormal is seen in the temperatures themselves, this leaves only thermal gradients (measured or unmeasured) as a possible explanation for the observed CAL-1 range changes in cycle 364.

Conclusion

We note that the magnitude of the recent CAL-1 range change is only half a centimeter so it is the rate of the change, not the magnitude, which we find puzzling. These recent CAL-1 range changes are qualitatively unlike anything seen in the previous TOPEX Side B history. For now we can only wait and continue to monitor closely the

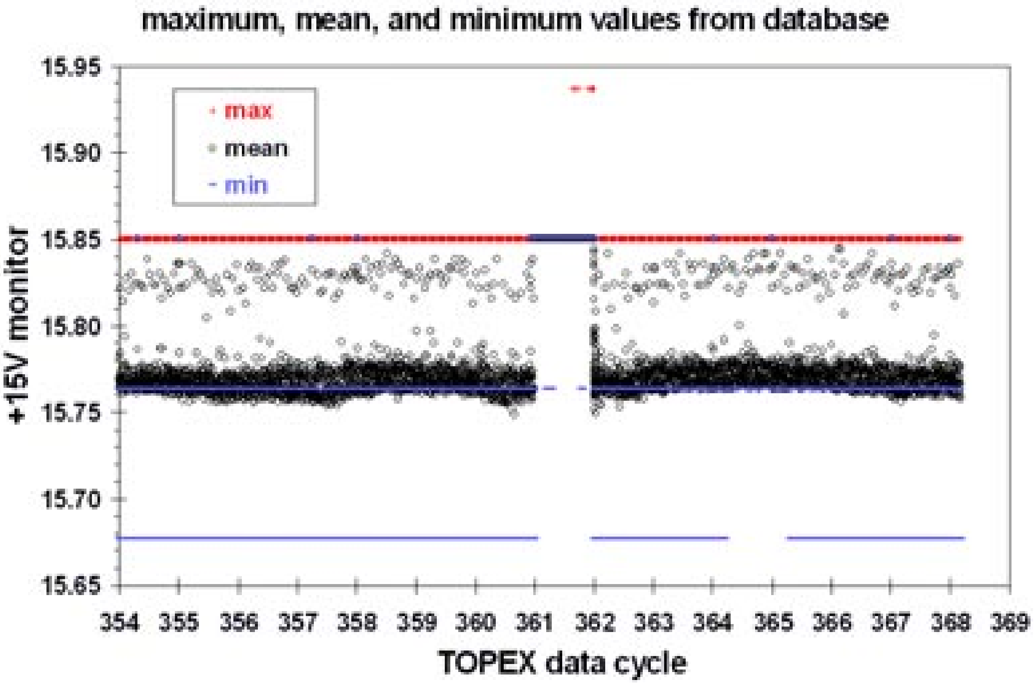

Figure B-7 TOPEX side B +15V Monitor vs. Cycle

altimeter data. In another month or so we expect to issue another update memo describing what has been seen in the additional three cycles of TOPEX data which will been have collected by then.

B.3 Changes in TOPEX Side B CAL Mode Range Trend Starting at Cycle 364 (January 16, 2003)

Introduction

The TOPEX altimeter contains an internal calibration mode (CAL-1, hereafter) which tracks a time-delayed portion of the transmitted pulse. There are CAL-1 ranges for both the TOPEX Ku- and C-band altimeters, and we have been monitoring the CAL-1-derived combined delta ranges for the entire TOPEX lifetime. “Combined” refers to that weighted sum of Ku- and C-band results which eliminates path delays due to the ionospheric electron content, and “delta range” refers to the CAL-1 range after subtraction of an arbitrary but constant reference value. More calibration mode details are given by "TOPEX Altimeter Range Stability Estimates from calibration Mode Data", by G.S. Hayne, D.W. Hancock III, and C.L. Purdy, in TOPEX/POSEIDON Research News, JPL 410-42, Issue 3, pp. 18-22, October 1994 (available at http://topex.wff.nasa.gov/docs/RangeStabEst.pdf). TOPEX cycle-averages of the combined delta ranges are reported in “TOPEX Altimeter Range Stability Estimate Update,” G.S. Hayne (available at http://topex.wff.nasa.gov/docs/RangeStabUpdate.html, updated about once per month throughout the life of the TOPEX mission).

In August 2002 we described an apparent drift observed in the TOPEX altimeter’s internal calibration mode’s range measurement in the brief report “Discussion of TOPEX Side B CAL Mode Range Drift in Cycle 364”, G. S. Hayne and D. W. Hancock III, August 15, 2002 (available at http://topex.wff.nasa.gov/docs/CALldht.pdf). We reported then that the calibration mode combined (Ku & C) delta range had made a relatively sudden downward step of about 5 mm in the first half of cycle 364 and then was continuing at the new apparently stable lower value. The combined delta range change was almost entirely due to a change in the Ku-band CAL-1 delta range. Some three weeks after the August report, we saw that the CAL-1 combined delta range had not stayed at the 5 mm low value but had returned almost to the vicinity of its values prior to cycle 364, and we described this possible stability in another brief report “Discussion of TOPEX Side B CAL Mode Range Drift from Cycles 364 to 366,” G. S. Hayne and D. W. Hancock III, September 6, 2002 (available at http://topex.wff.nasa.gov/docs/sept_CALldht.pdf).

Even the September report was too optimistic. Since then the delta range has continued to meander in a way that we do not understand. Today’s report is only to try to characterize the odd history of the delta range in recent months; this report supersedes those of August and September 2002. Our Figures will concentrate on the combined (Ku & C) CAL-1 range change, because it is the combined range that is of interest to the end user of the TOPEX data; however, the recent CAL-1 combined range change is almost entirely due to a change in the CAL-1 Ku-band range, and the CAL-1 C-band range has very little if any change over the time of the Ku-band change.

CAL-1 Delta Range Results

Figure B-8 "Cycle Averages of TOPEX Side B CAL-1 Step 5 Combined (Ku & C) Delta Range Estimates, Plotted vs. Cycle" on page -11 presents the TOPEX cycle averages of the CAL-1-derived delta ranges for the combined Ku-and C-band result. The last complete data cycle in Figure B-8 is number 379. There are about 20 individual CAL-1 results in each of the cycle averages in Figure B-8, and the error bars indicate the standard deviations in the averages. Figure B-8 shows clearly that the CAL Mode delta range behavior changed at cycle 364.

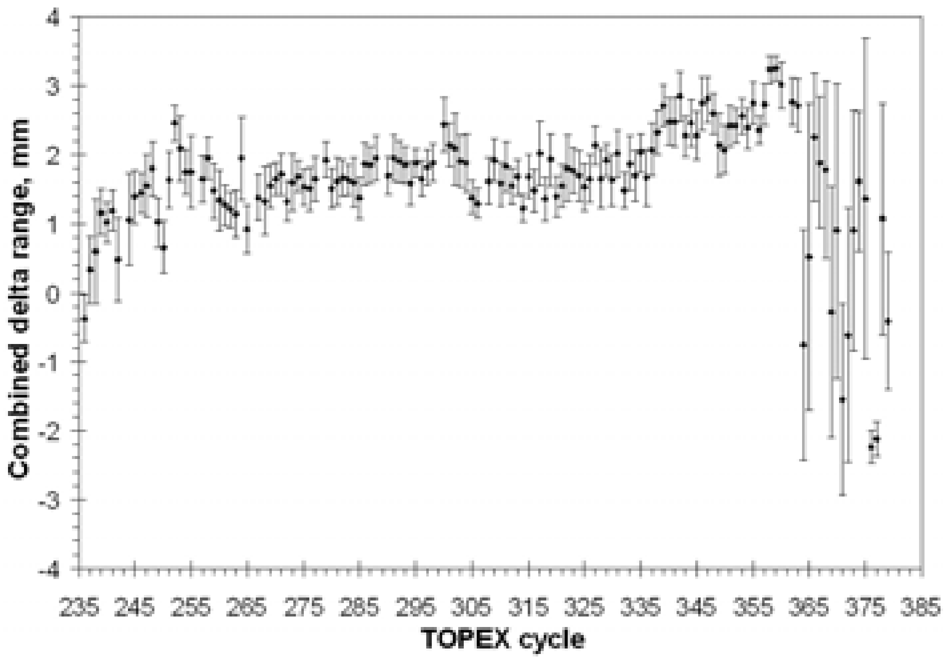

Figure B-8 Cycle Averages of TOPEX Side B CAL-1 Step 5 Combined (Ku & C) Delta Range Estimates, Plotted vs. Cycle

To look at all the data from which the Figure B-8 cycle averages were derived, Figure B-9 "All Side B CAL-1 Step-5 Combined Delta Range Values vs. Cycle" on page -12 presents the full-rate CAL Mode combined delta ranges for data from 2002 day 001 through 2003 day 012. Then Figure B-10 "Recent CAL-1 Step 5 Combined Delta Range Measurement vs. Cycle" on page -12 uses an expanded horizontal sCALe to show the CAL Mode combined delta range data starting at cycle 360. Both the full-rate data and the cycle averages are plotted in Figure B-10.

We repeat that, while this report has concentrated on the combined (Ku & C) CAL-1 range change, this CAL-1 combined range change is almost entirely due to a change in the CAL-1 Ku-band range. The CAL-1 C-band delta range has little if any change over the time of the Ku-band change and, unlike the Ku-band, there is no change in the CAL-1 C-band delta range characteristics before and after cycle 364.

Other investigations

We have seen no significant changes in the altimeter's point target response (PTR). The PTR is in effect the transmitted pulse shape as observed by the receiver, and through all of Side B operation the PTR has been monitored by execution of a special calibration sweep (CAL Sweep) mode approximately once per month. After the

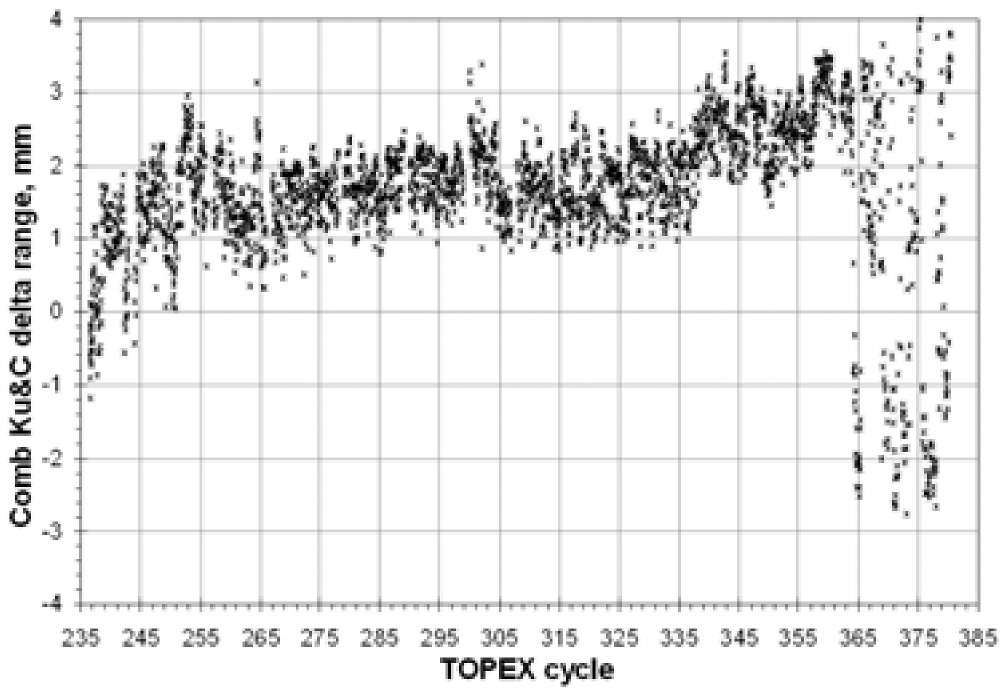

Figure B-9 All Side B CAL-1 Step-5 Combined Delta Range Values vs. Cycle

(asterisks = full-rate data, squares = cycle-averages

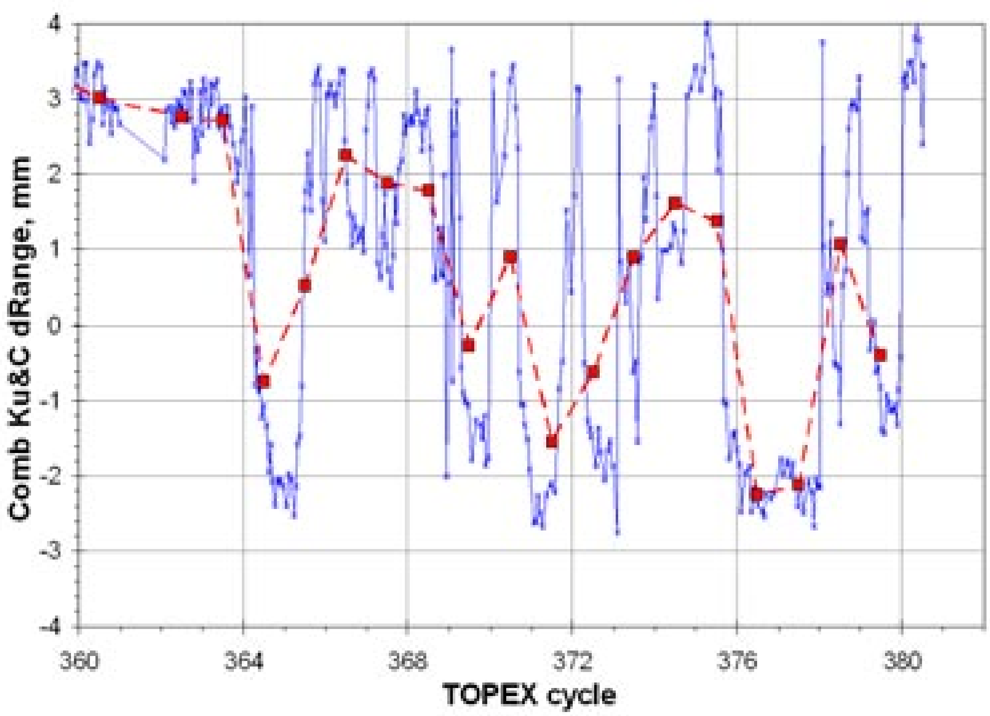

Figure B-10 Recent CAL-1 Step 5 Combined Delta Range Measurement vs. Cycle

appearance of the CAL-1 range change in cycle 364, the frequency of the CalSweeps was been increased and a CAL Sweep is now executed once every 10-day data cycle. We have examined the data from all CalSweeps and we have found no significant changes in any recent CAL Sweep's PTR compared to the PTRs from any of the earlier Side B CalSweeps.

A CAL Sweep starts as a regular CAL Mode, and the first four AGC steps proceed normally with about 10 seconds of data in each step. About 3-4 seconds into the fifth AGC step the altimeter's normal CAL Mode tracking is interrupted and the fine height is stepped through its entire range several times in a procedure lasting several minutes. From the first several seconds of CAL-1 Step 5 there is a normal CAL-range available. We have always deleted that CAL-1 range from our CAL-1 range data sets because all other CAL-1 ranges are based on about 10 seconds of data while the CAL-1 range from a CAL Sweep is based only on three seconds or so of data. Therefore Figure B-8 through Figure B-10 do not include the CAL-1 Step 5 results from any CalSweeps.

As indicated in our August 2002 report, we have searched in all the temperatures, voltages, currents, and powers which are monitored in the TOPEX engineering mode data, and have not found any parameters which were correlated with the CAL-1 range changes reported here. In September 2002 we thought that perhaps the +15 volt monitor had a very weak correlation with the CAL-1 range changes, but this has not been supported by the additional data since September.

Conclusion

We note that the magnitude of the recent CAL-1 range change is only half a centimeter so it is the rate of the change, not the magnitude, which we find puzzling. The recent CAL-1 range changes (since cycle 363) are qualitatively unlike anything seen in the previous TOPEX Side B history. For now we can only wait and continue to monitor closely the altimeter data.

Abbreviations & Acronyms

ACQ	Acquire
AGC	Automatic Gain Control
AIF	Altimeter Instrument File
ALT	Altimeter
ATA	Adaptive Tracker Assembly
ATU	Adaptive Tracker Unit
AVISO	Archivage, Validation et Interprétation des données des Satellites Océanographiques is the French multi-satellite databank dedicated to space oceanography, developed by CNES.
C	C-Band
CAL	Calibration Mode or Calibration Mode data
CAL / VAL	Calibration / Validation
CGEN	Chirp Generator
CM	Centimeters
CNES	Centre National d'Etudes Spatiales, the French Space Agency
CSSA	C-band Solid State Amplifier
dB	decibels
DCG	Digital C Gate
DFB	Digital Filter Bank
EML	Early / Middle / Late (Gate-Tracking)
ENG	Engineering Data
FTP	File Transfer Protocol
GDR	Geophysical Data Record
GSFC	Goddard Space Flight Center
ICA	Interface Control Assembly
ICU	S / C Interface Control Unit
IF	Intermediate Frequency
IGDR	Interim Geophysical Data Record
JASON-1	Follow-on mission to TOPEX

JPL	Jet Propulsion Laboratory
Ku	Ku-Band
LVPS	Low Voltage Power Supply
MCR	MOS Change Request
M	Meters
MM	Millimeters
MOS	Mission Operations System
MTU	Microwave Transmission Unit
NASA	National Aeronautics and Space Administration
NRA	NASA Radar Altimeter
PODAAC	Physical Oceanography Distributed Active Archive Center is one element of the Earth Observing System Data and Information System (EOSDIS), developed by NASA.
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval, period is 980 us.
PSU	Power Switching Unit
PTR	Point Target Response
RIU	Remote Interface Unit
RCS	Radar Cross Section
RCVR	Receiver
RF	Radio Frequency Subsystem
RMS	Root Mean Square
SACU	Synchronizer / Acquisition / Calibrate Unit
S / C	Spacecraft
SCI	Science
SEU	Single Event Upset
SSALT	Solid-State Radar Altimeter
SSH	Sea Surface Height
SSU	Signal Switch Unit
SW	Software
SWH	Significant Wave Height

TR	Tape Recorder
TM	Telemetry
TOPEX / POSEIDON	Ocean Topography Experiment
TOTM	TOPEX Orbit Transfer Maneuver
TRK	Track
TWTA	Traveling Wave Tube Amplifier
UCFM	Up-Converter / Frequency Multiplier
UTC	Universal Time Code
WFF	Wallops Flight Facility